Wastewater Re-use
Stormwater Management
and the
National Water Reform Agenda

J.F. Thomas / J. Gomboso / J.E. Oliver / V.A. Ritchie
Wastewater Re-use, Stormwater Management, and the National Water Reform Agenda

Report to the
Sustainable Land and Water Resources Management Committee
and to the
Council of Australian Governments
National Water Reform Task Force

J.F. Thomas, J. Gomboso, J.E. Oliver, and V.A. Ritchie

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Bibliography.


628.162
Preface

In June 1993, the Council of Australian Governments (COAG) requested that a Working Group of officials, under an independent chair, prepare a strategic framework for efficient and sustainable reform of the water industry, having regard for the technical and policy diversity existing across the States and Territories of Australia. In February 1994, COAG participants committed their governments to the Working Group’s recommendations with minor detailed modifications and, in September 1996, ARMCANZ (Agriculture and Resources Management Council of Australia and New Zealand) published *Generic National Milestones for Actions to Implement the Strategic Framework for Water Reform*.

As well as highlighting the need for reforms directed at improving the economic efficiency of the water industry, the Working Group drew attention to widespread natural resource degradation resulting from current water allocation and management, and urged all jurisdictions to arrest this process. The Working Group recommended that the strategic framework for reform should include environmentally sustainable management of wastewater and stormwater from metropolitan and town water services.

This is one of a series of studies coordinated by the Sub-committee on Water Resources of ARMCANZ as a response to the issues raised by the Strategic Framework for Water Reform, 1994.

The Terms of Reference are to:

- Examine the ramifications of making greater use of wastewater in urban areas, and strategies for handling stormwater, including its use, and
- Review current approaches to town wastewater and sewage disposal to sensitive environments, noting that action is underway to reduce accessions to watercourses from key centres on the Darling River system.

The first part of the Terms of Reference was undertaken in conjunction with the Australian and New Zealand Environment and Conservation Council (ANZECC). The second part was considered as a part of the development of the National Water Quality Management Strategy, also in conjunction with ANZECC. In developing the report, reference has also been made to the Ministerial Council for Planning, Housing and Local Government (MCPHLC).
The Study was undertaken under the supervision of a Steering Committee comprising:

David Mittelheuser, Department of Land and Water Conservation, New South Wales (Chairman)
Terry Scott, Melbourne Water
Alan Thomas, Commonwealth Environment Protection Agency
Volker Aeukens, Commonwealth Department of Primary Industry and Energy
Jonathan Thomas (Project Leader)

The CSIRO team was:

Jonathon F. Thomas (Project Leader)
Jeanette Gomboso
Janice E. Oliver
Veronica A. Ritchie.

A description of the work program is given in Appendix A. Terry Scott of Melbourne Water coordinated the National Effluent Re-use Survey reported in the study.

This report addresses issues raised by the policy principles of the COAG Water Reform Agenda in relation to the re-use of wastewater, improved urban stormwater management, and adoption of superior practices regarding disposal to sensitive environments. It is particularly concerned with the development of recommendations regarding:

- current and potential practices
- technical obstacles and opportunities
- environmental and public health constraints
- economic and incentive structures
- the regulatory environment
- the role of community involvement
- catchment-based resource management, and
- development of institutional roles and responsibilities.

The layout of the report follows the three topics which were addressed in meeting the terms of reference:

- Part 1 outlines a number of strategic issues for the water sector that follow from the National Water Reform Agenda, and outlines the problems encountered with discharges to sensitive environments
- Part II considers re-use of wastewaters
- Part III deals with stormwater management.
Following submission of this report as a draft in February 1996, a Policy Discussion Paper was coordinated by the Commonwealth Department of Primary Industries and Energy for consideration by ARMCANZ. However, the contents and conclusions of this report, are the responsibility of CSIRO, and are not necessarily endorsed by ARMCANZ, or the Department of Primary Industries and Energy.

Jonathon F. Thomas  
December 1996
Acknowledgements

The Project Leader thanks all members of the Study Steering Committee: David Mittelheuser, the Chairman, for his unstinting support and enthusiasm; Volker Aeukens, for his masterly guidance through ARMCANZ processes; Dr Alan Thomas, for his advice on ANZECC and MCPHLG linkages; and Terry Scott, who was responsible for the conduct of the National Effluent Re-use Survey.

Many others contributed essential information and constructive ideas, including Jeff Brown, Richard Clark, Pat Condina, Wally Fink, Don Gardiner, Peter Hoey, Fred King, Ian Lawrence, Cary Reynolds, Des Semple, and Ivan Unkovitch.

The assistance of Phillipa Wittenoom with literature review is gratefully acknowledged.

Finally the authors thank the external referees for their efforts in reviewing the final draft of this report. Nevertheless, CSIRO assumes all responsibility for the contents of the report.

Jonathon F. Thomas
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EXECUTIVE SUMMARY

This Executive Summary comprises five sections:

A. Overview of the Report
B. Environmental Background
C. Re-use of wastewaters
D. Improved management of stormwaters
E. Research needs.

A. OVERVIEW OF THE REPORT

A.1 This report presents possible policy directions for wastewater re-use and improved stormwater management, given the emerging water sector framework set out in the COAG National Water Reform Agenda.

A.2 The strategic framework for reform of the Australian water sector involves environmentally sustainable management of wastewater and stormwater from metropolitan and town water services. Specifically, an improved quality of natural environment needs to be sustained in urban regions, including the marine and estuarine environments of coastal cities, and the riverine or lacustrine environments of inland cities and towns.

A.3 In general, more intensive management of water supply systems is recommended, including:

- the use of reclaimed water within municipal and industrial systems
- the capture, storage, distribution and use of hitherto ‘uneconomic’ near-urban sources, such as local stormwater either of high initial quality or with treatment
- introduction of a quality-differentiated water supply: i.e., matching the quality and reliability of water supplied to each market segment to that actually needed by the user.

A.4 Improved management of the urban water cycle is needed to address growing problems of pollution, and to enhance the amenity values of urban waters.

B. ENVIRONMENTAL BACKGROUND

Wastewater and Stormwater in the Urban Water Cycle

B.1 The volumes of treated sewage and stormwater runoff are very large components of the urban water cycle. The amount of stormwater runoff varies with rainfall and land surface properties.
B.2 The following table, taken from the 1985 Review of Australia’s Water Resources and Water Use (Department of Primary Industries and Energy, 1987), illustrates this for the principal metropolitan regions.

Table i. Mean annual runoff, developed surface and groundwater resources, gross water consumption and wastewater flow in Australia’s metropolitan regions (GL)

<table>
<thead>
<tr>
<th>Water Region</th>
<th>Mean Annual Runoff</th>
<th>Average Yield of Developed Surface Sources</th>
<th>Groundwater Production</th>
<th>Gross Water Consumption</th>
<th>Wastewater Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brisbane</td>
<td>1860</td>
<td>555</td>
<td>60</td>
<td>331</td>
<td>116</td>
</tr>
<tr>
<td>Sydney</td>
<td>3900</td>
<td>581</td>
<td>11</td>
<td>620</td>
<td>424</td>
</tr>
<tr>
<td>Melbourne</td>
<td>1650</td>
<td>548</td>
<td>19</td>
<td>479</td>
<td>340</td>
</tr>
<tr>
<td>Adelaide</td>
<td>441</td>
<td>109</td>
<td>44</td>
<td>251</td>
<td>183</td>
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<tr>
<td>Perth</td>
<td>1260</td>
<td>213</td>
<td>226</td>
<td>369</td>
<td>76</td>
</tr>
</tbody>
</table>

Notes:
(i) All data are representative at 1985, except wastewater flow, taken from the National Effluent Reuse Survey, 1994 (this report)
(ii) The mean annual runoff data includes the Brisbane, Hawkesbury-Nepean, Yarra and Swan Rivers.

B.3 Stormwater and treated wastewater thus offer a large potential resource for economic and environmental benefits. The main factors which have limited their use have been the temporal variability of flow, limitations on available storage, and the quality of wastewater and stormwater.

B.4 Expected growth in Australian wastewater flows for 1994, 2000 and 2020 (derived from the National Effluent Reuse Survey 1994), is shown below.

FIGURE i. Australia-wide Volume of Wastewater
Impacts of Wastewater and Stormwater Discharges on Receiving Waters

B.5 Figure ii shows the distribution of effluent to various destinations in each state in 1994 from the National Effluent Re-use Survey. It is evident that discharges to coastal waters account for the majority of discharges in most states.

FIGURE ii. Volume of effluent discharged to various environments by state (1994)

B.6 Figure iii shows that the relative proportions of effluent being discharged to various environments are not expected to change very much over the next 25 years.
FIGURE iii. Per cent of effluent discharged, by category (1994–2020)
Coastal waters

B.7 Although controls on discharges of wastewater and stormwater to sensitive environments are showing signs of improvement, coastal waters near urban concentrations are still suffering from declining water and sediment quality; loss of marine and coastal habitat; unsustainable use of marine and coastal resources; and the lack of strategic, integrated planning. Key problem areas are:

- elevated levels of nutrients and sedimentation in coastal water bodies near urban areas, which are largely the result of inappropriate catchment land use practices, sewage discharges and urban runoff
- algal blooms, including blue-green algae which are now common in many estuaries and bays. Eutrophication is a serious threat to estuaries, temperate sea grass and tropical corals
- increased litter, reducing the recreational and scenic value of many coastal areas, and affecting wildlife
- heavy metals including mercury, cadmium and lead present in urban wastewaters and
- organochlorines or chlorinated compounds used as herbicides and insecticides in agriculture and industry which are toxic to marine life and are bio-accumulated in marine food chains.

B.8 Coastal lakes, which have limited ocean water exchange, have been particularly affected by terrestrial runoff. Significant losses of saltmarsh and mangroves around urban areas, caused by reclamations, drainage, and other developments, are affecting fish and other sea life which use the mangrove areas as nurseries and feeding grounds.

B.9 The need to provide enhanced protection of coastal environments has been recognised by the Commonwealth, States and Territories. The Resource Assessment Commission (1993), for example, made many recommendations including a National Coastal Action Program to be implemented by all three levels of government in consultation with industry and community groups. Existing coastal water quality protection policies include:

- catchment management programs to reduce soil erosion and discharge of nutrients to receiving waters
- systems of water quality protection for specific uses
- the National Water Quality Management Strategy (NWQMS), which will provide a general framework of guidelines for water quality management in the coastal zone
- National State of the Environment Reporting Program, under which a set of environmental indicators is proposed to be developed for future quantitative reporting.

B.10 Results of the National Effluent Re-use Survey, 1994 conducted in this study indicate that discharges of town wastewater to coastal waters could increase by 50% between 1994 and the year 2020.
B.11 Improved wastewater and stormwater management can help in addressing:

- declining quality of marine and coastal water and sediments, particularly as a result of inappropriate catchment land use practices
- loss of marine and coastal habitat
- unsustainable use of marine and coastal resources and
- lack of strategic, integrated planning in the marine and coastal environments.

**Inland waters**

B.12 Australia’s inland rivers are subject to many environmental problems. Most relevant to wastewater re-use are increased nutrient levels and altered flow regimes.

B.13 The National Effluent Re-use Survey, 1994 indicates that discharges of town wastewaters to Australian inland/fresh waters will increase in volume by 30%, between 1994 and the year 2020. However, in NSW and Queensland the increases will be 70% and 55% respectively unless there is a reduction in wastewater flow or an increase in projected reuse, including land disposal.

B.14 In response to rising concern at the level of nutrients and eutrophication, the Murray-Darling Basin Commission has established a nutrient management strategy. In 1992 a Blue-Green Algae Taskforce considered control actions, including the reduced nutrient discharges from sewage treatment plants. The Commonwealth has since provided $60 million for upgrades of town sewage treatment plants in the Darling system.

B.15 In line with recommendations in the 1994 Algal Management Strategy for the Murray-Darling Basin, discharges to all inland waters should be managed to control nutrient concentrations in receiving waters, and to improve flow regimes. Further:

- wastewater re-use and land application systems should be implemented where appropriate and cost effective
- water quality monitoring programs should be enforced where discharge to water bodies will continue in the future, and
- new urban developments should be monitored to ensure that pollutants are not accumulating in local waters.

**C. RE-USE OF WASTEWATERS**

**Potential for Re-Use**

C.1 All Australian jurisdictions should recognise that re-use of wastewaters presents a viable and attractive alternative source of water supply, which may contribute to the abatement of environmental problems.

Specifically, there is potential for wastewater re-use schemes to:

- augment limited primary water sources
- help prevent excessive diversion of water from alternative uses, including the natural environment
- manage in-situ surface and groundwater resources
• minimise infrastructure costs, including total treatment and discharge costs
• reduce or eliminate discharges of treated sewage to receiving waters, and
• satisfy political, community and institutional constraints.

C.2 In general, sewage offers a better source for reclamation and re-use than storm-water runoff from developed areas. This is because its flow is regular, the collection system is in place, treatment facilities already exist, and the contaminants present in individual sewage streams are known and temporally relatively invariate. However, there is also considerable scope for improved management of stormwater runoff from less-developed parts of urban regions so as to achieve some re-use, improved landscape features, better flow regulation and improved pollution outcomes for receiving waters.

C.3 New treatment technologies and methods of hydraulic, hydrological and geohydrological management are increasing the scope for wastewater re-use and improved management of stormwater, and reducing the relative costs.

C.4 The relative costs of continuing to employ traditional approaches are increasing in both economic and environmental terms.

C.5 Internationally, there is increasing adoption of the new approaches. In OECD countries, some cities now provide up to 30% of their total water needs from reclaimed wastewater.

C.6 A more sophisticated water market in urban areas would provide quality-differentiated supplies for appropriate market segments. The study has concluded that a variety of urban water demands could be effectively supplied by reclaimed water, either to potable or non-potable standard.

• The potential residential market for reclaimed water is large. New developments, where dual reticulation can be incorporated into the design and costing, offer the best opportunities.
• As the cost of treating water to potable standards decline, this option may become more attractive over time.
• Without adequate levels of treatment, greywater is probably only acceptable for sub-surface garden irrigation. In this case, capital costs of setting up these schemes may be the major limitation.
• The market for urban irrigation depends on the amount of public open space and the level of irrigation required. Although small in overall terms, the urban irrigation market can be significant in reducing discharges to sensitive environments.
• Industrial use of reclaimed water is an important market. Industry and commerce use approximately a third of urban water in Australia and the demand pattern is relatively constant throughout the year. Due to the variations in water quality requirements of different markets, adequate treatment levels must be ensured to avoid problems such as corrosion, staining, scale deposition and foaming.
• Irrigated agriculture and woodlots on the fringes of urban areas is an important market
• In country towns, there is also considerable scope both for re-use in irrigation, and for land disposal.

C.7 In the longer term there is the opportunity to re-configure the water supply and wastewater systems even in established areas. The present water infrastructure is quite old in parts, and has been developed over a period when management objectives were very different. Hence, the retrofitting of existing areas with dual reticulation systems, possibly from treatment plants built on existing trunk sewers, is becoming a feasible option, both technically and economically. Advances in trenchless technology are reducing the costs of retrofitting with dual reticulation. As the number of technical options increases there is increasing need to evaluate decentralised systems against the more traditional centralised systems. Finally, redevelopment provides an opportunity for a re-assessment of the storm drainage system, and integrating it with total water cycle management.

Planned Re-Use

C.8 The population of Australian states and territories is increasing. Wastewater flows have also been increasing, with resultant demands for new disposal facilities. Results of the National Effluent Re-use Survey, 1994 suggest that total wastewater flows into treatment plants may increase by nearly 50% between 1994 and 2020.

C.9 The combined effects of these trends is that a greater amount of wastewater will have to be disposed of, or re-used in the future. While the implementation of water demand management programs including economic pricing will tend to reduce total wastewater flows, these policies will not influence the pollutant loads in wastewater which are likely to continue to increase on a per capita basis.

C.10 Table ii gives the reported wastewater flows in each state and territory in 1994, and summarises current expectations of future volumes and the distribution of discharges to land and water.

C.11 While total re-use nationally is expected to increase from 18 GL in 1994 to 64 GL by the year 2020, this falls far short of the total estimated increase in wastewater flow of 800 GL over the same period. Consequently, wastewater utilities are generally projecting continued increases in discharge to coastal and inland waters.

C.12 However, the above projections of direct re-use and discharge to land should be regarded as minima, based on confirmed schemes or adopted targets at the State/ Territory level. In future it is likely that utilities will seriously examine re-use options and that the actual outcome will be for more re-use than appears from these projections, especially if the recommendations in this report are implemented.
Table ii. Current and future discharge volumes, 1994 to 2020 (GL/yr)

<table>
<thead>
<tr>
<th>Disposed to:</th>
<th>ACT</th>
<th>NSW</th>
<th>NT</th>
<th>QLD</th>
<th>SA</th>
<th>TAS</th>
<th>VIC</th>
<th>WA</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In 1994</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Land</td>
<td>–</td>
<td>28</td>
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<td>31</td>
<td>7</td>
<td>–</td>
<td>82</td>
<td>13</td>
<td>162</td>
</tr>
<tr>
<td>Direct re-use</td>
<td>–</td>
<td>9</td>
<td>–</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Inland/fresh</td>
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<td>waters</td>
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<td>240</td>
<td>93</td>
<td>35</td>
<td>326</td>
<td>77</td>
<td>1225</td>
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<tr>
<td><strong>Total</strong></td>
<td>33</td>
<td>618</td>
<td>11</td>
<td>304</td>
<td>105</td>
<td>50</td>
<td>483</td>
<td>94</td>
<td>1700</td>
</tr>
<tr>
<td><strong>By 2020</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Land</td>
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<td>–</td>
<td>135</td>
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<tr>
<td>Direct re-use</td>
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<td>29</td>
<td>–</td>
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<td>3</td>
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<td>13</td>
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<td><strong>Total</strong></td>
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<td>15</td>
<td>471</td>
<td>112</td>
<td>60</td>
<td>639</td>
<td>198</td>
<td>2519</td>
</tr>
</tbody>
</table>

Source: National Effluent Re-use Survey, 1994 (this report)

Implications for the COAG National Water Reform Agenda

C.13 Key elements of the COAG framework deal with pricing, contestable markets, water allocation and entitlements, institutional arrangements, consultation and education needs. These categories have been used to structure the recommendations, given below.

Pricing and contestibility in water markets

C.14 In relation to costs, which directly govern price levels, it is recommended that:

- urban water demands need to be satisfied at acceptable social costs (including direct and indirect costs of disposal) by means which reduce the aggregate volume diverted from ‘non-urban’ uses
- emerging cost pressures associated with augmenting water supplies through traditional water sources need to be alleviated
- the emerging escalation of maintenance and replacement costs, needs to be addressed through more efficient infrastructure concepts
- the volume of sewage required to be transported long distances across cities for treatment must be reduced
- the environmental costs of disposal need to be minimised.

C.15 Water industry regulators in each jurisdiction should ensure that inefficient institutional impediments and cost or pricing distortions affecting potential re-use projects are removed. In particular, the pricing of reclaimed water should reflect its system-wide costs, including cost savings achieved at the source and sink ends of the water cycle through the introduction of re-use projects. Alternatively the pricing of conventional water-sewage systems should reflect environmental damage and
abatement costs. In some situations compensation may need to be paid to water utilities under the community service obligations framework for this to occur.

C.16 Water industry regulators should examine the full range of opportunity costs of raw water diversion by industries, agriculture, commerce, local authorities, the public sector and private households; and impose cost recovery and resource rental charges where appropriate.

C.17 Corporatised water utilities should not be allowed to pre-empt fair competitive water supply activities including re-use projects by other groups. Specifically, the following should be discouraged:

- charging non-users of utility infrastructure (for example, charging sewage rates irrespective of whether a household is connected)
- denying third party access to wastewater flows for legitimate re-use purposes
- cross-subsidising particular high-cost conventional water supplies and contractual arrangements with related organisations such as suppliers, water retailers, and build-own operators or water users, which exclude competitive supply activities involving re-use.

C.18 Governments and water industry regulators should promote contestability in water markets by actively supporting requests for access to water infrastructure and water resources, including wastewater, by third parties such as households, industry, commerce, local government, universities and the public sector generally; and by permitting such entities to engage in water production including reclamation, subject to the normal public interest conditions.

Water allocation and entitlements

C.19 It is not always clear whether a corporatised or privatised wastewater utility actually owns the sewage that it transports and treats. A clearer definition of ownership of wastewaters, and more clearly defined allocation rights and responsibilities for wastewater is required.

Regulatory framework

C.20 Three regulatory structures are essential for successful wastewater reclamation projects:

- an economic regulator: to ensure contestable markets and pricing
- an environmental/water resources regulator: to ensure that target quality of receiving waters is set appropriately, and is met by the industry
- a quality control regulator for the reclamation process.

C.21 While the first two are generally present in Australian jurisdiction, more attention needs to be paid to the third if there is to be an active water re-use industry. State and Territory governments should establish independent regulatory jurisdictions governing the operations of re-use projects. These should require weekly plant perform-
ance data and exception reports from wastewater agencies, plus some monitoring of
the distribution system for reclaimed water.

C.22 In all States and Territories throughout Australia, the approval of both the
Health Department and the Department of Environmental Protection should be re-
quired before re-use schemes can proceed.

C.23 The NWQMS Draft Guidelines on wastewater re-use should be adopted as the
basic standard for wastewater re-use in Australia. The Draft Guidelines should be
expanded in order to relate reclaimed water quality guidelines more closely to the
technologies to be employed in applying the product water. Editor’s Note: this
recommendation was adopted and influenced the final Guidelines.

C.24 An additional set of NWQMS Guidelines should be promulgated for artificial
injection of urban wastewaters into groundwater aquifers for subsequent re-use, based
on research recently conducted on behalf of Urban Water Research Association of
Australia (UWRAA) by the CSIRO Centre for Groundwater Studies (CGS).

Consultation and education

C.25 Communities currently express mixed views on the acceptability of re-use
schemes. There is public resistance to current disposal methods, which have been seen
as both environmentally damaging and the waste of a potentially valuable resource.
On the other hand, the community needs assurance about public health implications
associated with wastewater re-use.

C.26 Community education and pilot demonstrations of re-use projects should be
couraged. Public education and public involvement programs should include
schools programs, visitor programs to treatment facilities, general public information
provisions and community involvement in decision making about new re-use
schemes. Water utilities and governments should ensure that the public is well
informed about re-use schemes and involved in decisions to undertake them.
Treatment schemes should include the necessary precautions to ensure that the
potential risk of disease transmission is within acceptable limits.

D. IMPROVING STORMWATER MANAGEMENT

Management Objectives

D.1 Internationally, a revolution is taking place in the way the water cycle of urban
areas is planned and managed. In Australia this is related to increasing evidence of the
environmental impacts of stormwater discharges.

D.2 More attention is being given to water issues in urban planning, landscape
management and environmental management, so as to naturalise urban water courses
and water bodies, and to harvest and store treated wastewater and stormwater,
including the artificial recharge of aquifers near towns and cities. Stormwater
management objectives are thus being widened so that re-use, pollution control, envi-
ronmental amenity and ecological integrity are being set alongside traditional flood
control objectives for drainage systems. These additional objectives are not generally in conflict with flood control objectives, but they do imply a considerable broadening of design considerations, and the extension of responsibility for stormwater pollution management to all sections of society.

D.3 For new urban developments, the concept of integrated water cycle management and the related development of water-sensitive urban design guidelines, are replacing traditional drainage design principles. In older urban areas, large costs are being faced for upgrading old and degraded systems, particularly where sewer overflows contribute to stormwater pollution.

D.4 Water-quality parameters were not a design criterion for many existing drainage systems during their planning. Stormwater systems in Australian cities are either under-designed or under-performing due to deterioration, inadequate attention to satisfying all management objectives, insufficient capital and operational expenditure, inadequate technical implementation, lack of public commitment and inappropriate institutional structures.

Management Practices

D.5 A wider set of stormwater management practices needs to be applied. These generally require action by numerous agents in society, as well as drainage utilities.

D.6 Stormwater management practices may be usefully categorised as:

- structural verses non-structural and
- source control verses in-line controls verses end-of-pipe treatments.

D.7 New technical developments will make the achievement of multi-objective management of stormwater systems easier in the future, given an institutional structure that encourages innovation.

D.8 While Australian cities generally have separate storm drainage and sewer systems, internationally there is a growing consensus that a mixture of combined (sanitary and storm sewers) and separate systems is likely to be optimal for many urban regions. The dangers of illicit discharges to storm drains and sewers, and the difficulties of preventing cross-connections in separate systems are strongly emphasised.

Implications for the COAG National Water Reform Agenda

Pricing

D.9 There should be reform of existing drainage rating systems, which should be replaced by charges on households and organisations which more accurately reflect the costs of planned stormwater management programs.

D.10 More attention should be given to the design of polluter-pays systems under which the owners of urban stormwater systems should pay state governments
according to the level of pollution discharged to receiving waters. However, this recommendation is unlikely to be acted upon in the absence of institutional reform (see below).

**Institutional reform**

**D.11** Within most jurisdictions there is a need for extensive reform of the institutional structures for stormwater management, to complement the corporatisation of water utilities and to create explicit roles for state and local governments. While the application of the principles for institutional development so far enunciated and accepted by COAG is necessary, the principles are not in themselves sufficient for improved stormwater management. In all jurisdictions, the responsibilities defined at state level for setting the broad water resource and environmental policies need to be separated from those of detailed stormwater catchment planning and management undertaken by urban catchment management bodies.

**D.12** The principle of separation of powers and responsibilities, and the historical and potential future roles of local governments, imply that bodies established for the purpose of urban catchment management should preferably be owned by local governments and be accountable to environmental regulators at state/territory level for the achievement of agreed targets within a polluter pays framework.

**D.13** In all jurisdictions the statutory objectives of urban catchment management bodies should include flood management, water quality, environmental amenity and ecological integrity. Stormwater management targets should be set with reference to the National State of the Environment Reporting System.

**D.14** Urban catchment management bodies should have the power to obtain revenue either from local government or through direct charges on households and organisations in the private and public sectors, to employ relevant staff and to commission works. Catchment bodies should be empowered to set up contractual undertakings by other organisations in the public or private sectors to carry out the catchment management program. They should also have the power to institute stormwater management by-laws, including those related to the introduction of economic instruments. They should publish annual reports of their operations and planning activity.

**D.15** The roles and responsibilities of catchment management bodies should include the preparation of catchment management plans which:

- identify catchment conditions requiring attention and articulate existing priorities of the managing agency
- satisfy specific water quality objectives, particularly regarding conservation of scarce resources and provision of a range of environmental needs
- list possible management responses, including both structural and non-structural options, and considering source control as well as pollution interception
- specify a stormwater management program which identifies costs, timelines, and the agencies which are to be responsible for carrying out each required action
- put in place a consultation process that improves the coordination of policies, and
- provides a framework for multi-functional planning.
D.16 Deciding on the appropriate level of investment in stormwater management programs requires some judgement about whether the projected flood control and pollution abatement expenditures needed to attain various target levels of outcome, are justified in economic terms. In general, the amount of economic resources allocated to urban stormwater management should be increased in line with required abatement expenditures.

D.17 Best Management Practices (BMPs) must be selected carefully to provide the highest value for money spent. Economic analysis must consider operational and maintenance costs as well as capital expenditures, as these constitute the greater part of total costs at all treatment levels considered.

D.18 Managers of stormwater programs need to ensure that account is taken of ongoing maintenance and performance-monitoring requirements.

D.19 Technical innovation and multi-objective management of stormwater systems should be encouraged. The potential for a mixture of combined (sanitary and storm sewers) rather than the separate storm drainage and sewer systems which currently exists in Australia should be evaluated.

Urban planning

D.20 The approach of *water-sensitive urban design* should be strongly supported as one method of dealing with urban change, via the:

- recognition of stormwater and wastewater as a resource
- increased treatment of stormwater and wastewater for re-use, in order to reduce demand on the drinkable water resource, and
- use of integrated catchment management as the primary water management tool.

D.21 Principles and guidelines are needed for the development and implementation of integrated design approaches to achieve sustainable levels of environmental enhancement in urban floodways and corridors. Stormwater management design approaches require sensitivity to ecological aspects, planning, landscape design and local cultural/historical needs, and should be done in the context of master plans describing land use, drainage requirements in terms of flow paths, flow detention devices, and pollution control.

D.22 For new urban developments, integrated water cycle management and the related development of water-sensitive urban design guidelines, need to replace traditional drainage design principles.

D.23 Given the complexity of any stormwater management plan, some overall assessment framework encompassing bio-physical, economic, equity and other issues is needed. Multi-objective analysis, that takes account of expected biophysical outcomes, projected abatement expenditure levels, specific damage costs, and other features of the plan that are not measured in monetary terms is one such framework.
Consultation and education

D.24 Public education and public involvement are important elements of any stormwater management program, and should be encouraged. The total catchment management movement so evident in rural Australia needs adaptation if it is to be successful in urban areas. There needs to be better general understanding of how the behaviour of individuals can really help to address stormwater objectives, particularly in the area of a number of gross pollutants. Individual initiative need to be accompanied by clearer definitions of institutional roles, required public investment, technical advice and environmental policies that deal with systemic inadequacies.

D.25 The Commonwealth should support a new Urban Water Care Movement. Initial components could include:

- a public awareness campaign ($2 million/yr for 3 years)
- educational materials ($2 million/yr for 3 years)
- support for community groups in urban catchments ($2 million/yr for 3 years)
- loan scheme for local authorities engaging in urban catchment management programs ($5 million/yr for 10 years) and
- capital grants for minor capital works which demonstrate pilot schemes, and management methods for water reclamation and integrated stormwater management ($20 million/yr for 5 years).

D.26 Although public information is an important component for raising community awareness, based on international experiences, more efforts should be devoted to encouraging the community to provide comment and feedback on stormwater management practices.

D.27 Compliance should be recognised as the key to the success of various stormwater control policies (such as pet control), and this may be achieved by both enforcement and community education/cooperation.

D.28 Drain labelling is a means of increasing public awareness of stormwater systems. Community stormwater groups may take on the drain labelling program as a specific task. The dumping of paints, oils, solvents and garden cuttings into drainage systems are particular target activities that might be modified by increased awareness.

D.29 The general promotion of recycling is recommended as an important part of product controls, and particularly the re-cycling of packaging materials which constitute a significant portion of litter in stormwater.

E. RESEARCH NEEDS

E.1 The Commonwealth should set up a new Research and Development Corporation for the Urban Environment, including the urban water environment. It should deal with issues of urban water cycle management, water pollution, air pollution, energy use and waste management. The budget should be similar in size to that of the Land and Water Resources Research and Development Corporation, which is focussed on non-urban resource management issues.
E.2 There is an urgent need for a national research project to examine options for improved urban water cycle management and infrastructure cost reduction. This should be supported by the Commonwealth in association with the Water Services Association of Australia.

E.3 It is recommended that a national study of the direct and external costs and benefits of conventional versus re-use water systems be undertaken under the auspices of UWRAA (Sections 12.3 and 14.4). There is a growing need for environmental economic studies that:

- demonstrate the community’s willingness to pay for improved water quality in urban regions
- provide estimates of environmental damages associated with the degradation of sensitive environments, and
- develop indicative estimates of the cost schedule for ascending levels of abatement.

E.4 A national survey of community attitudes and knowledge of issues relating to water re-use is needed as a basis for planning further community involvement in water re-use planning and implementation.

E.5 Further research is needed into the hydrological and ecological implications of effluent and stormwater discharges in sensitive environments.

E.6 Research into Australian microbial species that may be associated with re-used wastewaters should be encouraged.

E.7 Research into methods of storage and of seasonal demand equalisation for reclaimed water should be supported.

E.8 A case study in a newly-developing urban region should be supported by the Commonwealth in which concepts and prototype designs for integrated urban water resources management are demonstrated. This could be a world-first.
PART I:

BACKGROUND
1. COAG’S STRATEGIC FRAMEWORK

The COAG Working Group on Water Reform, 1994, advocated that a strategic framework for the water sector be adopted throughout Australia based on eight policy principles, as follows:

- water policy should deliver on the agenda for ecologically sustainable development
- pricing should reflect supply costs, including environmental costs, with all cross-subsidies and community service obligations being made transparent
- there should be consistency in pricing, property rights, water trading and environmental allocations
- water should be employed in higher value uses within the social, physical and ecological constraints of catchments
- institutional arrangements and responsibilities should be clearly defined
- an integrated catchment management approach should be used in water resource management
- measures to address structural and social impact of reform should be implemented
- there should be community involvement in the reform process.

The COAG framework thus raises new questions for the managers of sewage and stormwater. This part of the report provides an overview of strategic developments which are likely to affect future opportunities and constraints for the planning and management of wastewater and stormwater systems. Economic and technical issues are considered first. Sections 3 and 4 provide an overview of issues, policies and practices related to the discharge of wastewaters to sensitive environments. The marine environment, including coastal rivers, lakes and estuaries is presented in section 3, and the inland river basins in Section 4. In this report both sewage effluents and stormwater runoff are considered as wastewaters. Finally, Section 5 introduces the issue of changing institutional roles and responsibilities.

2. ECONOMIC AND TECHNICAL BACKGROUND

2.1 Demand of Urban Areas on the Water Resource

Urban areas use only 21% of Australia’s diverted water resources (Department of Primary Industries and Energy, 1987). However the water that is diverted for urban use, which is mainly drawn from areas close to the towns and cities, is of very high value, both in its current use, and in alternative uses. These alternative uses are often
derived from the proximity of the city itself, and include high-value crop irrigation, recreation and maintenance of the natural environment.

The diversion of water to urban uses, including residential, commercial, social and industrial applications thus involves a transfer from lower to higher-value uses. Such transfers are often economically optimal. But it is also true that if urban demands can be satisfied at an acceptable cost by means which reduce the aggregate volume diverted from the alternative ‘non-urban’ uses, then society as a whole will be better off. The re-use of wastewater and harvesting of stormwater are clearly of interest as possible method of achieving this aim.

### 2.2 Costs

For some Australian towns and cities the future costs of augmenting water supplies will be high if development continues to rely on conventional sources. For example, when water demand reaches the current capacities of pipelines that supply Adelaide and the Northern Spencer Gulf from the Murray River, further conventional source development will be costly, requiring new long-distance pipelines. Problems of high cost for additional water supplies are encountered in remote towns of arid Australia which exist to service the mineral and processing industries. More intensive use and recycling of locally-available water may contribute to the avoidance of such high costs.

Within some metropolitan areas the costs of water supply and sewerage are high simply because the upgrading of cross-city trunk capacity is expensive. For example, augmentation of Melbourne Water’s capacity to supply developments in its western region involves long-distance trunk mains. More intensive urban water cycle management offers hope of alleviating some of these emerging cost pressures, by reducing the capacity requirements for such cross-metropolitan transfers. The same applies with sewerage. For example, any urban development on the northern periphery of Melbourne would require increased trunk sewer capacity to the two main sewage treatment plants located in the south east and south west of the metropolitan area. Any means of reducing the volume of sewage required to be transported long distances across the city for treatment is likely to have a high benefit.

Another cost pressure is coming from society’s insistence that a higher quality of natural environment should be sustained in urban regions, including the estuarine and marine environments of coastal cities, and the riverine or lacustrine environments of inland towns and cities. The costs of end-of-pipe abatement facilities required to reach target environmental quality can be very high. Water utilities have no alternative but to pass these costs on to consumers.

Finally, the Australian water sector is facing an emerging cost escalation through the need to maintain or replace ageing infrastructure. The works that were undertaken in the period of rapid urban growth dating from the middle of this century are now beginning to require refurbishment. The full impact of this will be felt in the early
decades of the 21st century. Replacement infrastructure could include re-use features and higher performance standards for sewer overflows.

<table>
<thead>
<tr>
<th>In terms of urban water-related costs, it is recommended that:</th>
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<tbody>
<tr>
<td>• urban water demands should be satisfied at an acceptable cost by means which reduce the aggregate volume diverted from the alternative ‘non-urban’ uses, thereby making society as a whole better off</td>
</tr>
<tr>
<td>• emerging cost pressures associated with augmenting water supplies through traditional water sources need to be alleviated</td>
</tr>
<tr>
<td>• the emerging escalation of maintenance and replacement costs, needs to be addressed by more efficient infrastructure concepts, and</td>
</tr>
<tr>
<td>• the volume of sewage required to be transported across cities for treatment must be reduced.</td>
</tr>
</tbody>
</table>

2.3 Externalities

Following the corporatisation or privatisation of water utilities, any environmental benefits or costs resulting from fresh water diversion or wastewater discharges become externalities that are not reflected in the utilities’ financial accounts, unless some other institution imposes charges on (or payments to) the utility reflecting these social costs (or benefits). The external impacts could not, therefore, be expected to be taken into account in the unfettered decisions of the utilities. From the point of view of society as a whole this would lead to a misallocation of resources. Or, in engineering terms, the wrong choice of system design. Whether this danger is to be averted by direct regulation or by some other form of institutional intervention is discussed later in the report.

2.4 Technical Change

Technical change is opening up a greater range of supply-side possibilities. These include opportunities for more intensive management of the urban water cycle (that is: the water that falls on, is stored within, and moves through the natural and built environment of the cities). More intensive management may take numerous forms, including:

• the use of reclaimed water within municipal and industrial systems
• the capture, storage, distribution and use of hitherto uneconomic near-urban sources, for example, local stormwater either of high initial quality or with treatment
• introduction of a quality-differentiated water supply: (that is: matching the quality and reliability of water supplied to each market segment to that actually needed, rather than delivering a standard product to everyone at the quality and reliability levels required by the most stringent user), and
• basing new urban developments on the principles of water-sensitive urban design, which are conservative in their water use characteristics and which offer more scope for re-use in many forms.

The approach of water-sensitive urban design has been strongly supported by the Commonwealth through the Better Cities Program (BCP), which was established to
demonstrate new approaches to problems of dealing with urban change in the 1990s. The principles enunciated by the BCP (Phillips and Goffman, 1993) were:

- recognition of stormwater and wastewater as a resource
- increased treatment of stormwater and wastewater for re-use, in order to reduce demand on the drinkable water resource
- the use of integrated catchment management as the primary water management tool, and
- adoption of a water-sensitive approach to urban design.

Modern treatment methods, such as micro-filtration, vortex clarification or reverse osmosis, are economical, and moderate in their use of land, at relatively low design capacities. This, and the increasing availability of good engineering advice, makes two things possible. Firstly, managers may find that more decentralised configurations of the sewerage system involving local re-use become optimal, because it becomes less important to transport sewage over long distances for treatment at a central plant. Secondly, it becomes feasible for both utilities and other organisations to develop options for water supply based on reclaimed sewage, other process water, or locally-captured stormwater. Non-utilities that could compete in water supply might include local governments, universities, private sector developers and industries.

The future technical evolution of the urban water system thus intersects very strongly with the theme of competition policy. Should, for example, a water utility be obliged to give a local authority access to a source of treated sewage for reclamation purposes, under the Trade Practices Act, thus increasing the degree of contestability of supply? Will the new corporate structures encourage technical innovation, or will monopolistic or oligopolistic structures prevail which will be able to minimise commercial risk by perpetuating older technologies and passing costs on to consumers? It is difficult, for example, for utility regulators to insist that specific technological choices be made by the water industry.

More intensive management of water supply systems is recommended, including:
- the use of reclaimed water within municipal and industrial systems
- the capture, storage, distribution and use of hitherto ‘uneconomic’ near-urban sources, e.g. local stormwater either of high initial quality or with treatment, and
- introduction of a quality-differentiated water supply: that is, matching the quality and reliability of water supplied to each market segment to that actually needed by the user.

The approach of **water-sensitive urban design** should be strongly supported as one method of dealing with urban change, via the:
- recognition of stormwater and wastewater as a resource
- increased treatment of stormwater and wastewater for re-use, in order to reduce demand on drinkable water resource and
- use of integrated catchment management as the primary water management tool.
3. DISCHARGE OF WASTEWATERS TO THE MARINE ENVIRONMENT

This and the following section, presents an overview of issues concerning the discharge of wastewaters to sensitive environments. Appendix B gives examples of marine disposal issues.

3.1 Sensitive Marine Environments – Definition

In this report we have adopted the definition for ‘sensitive marine environment’ put forward by an ANZECC Working Group on Pollution and Shipping Incidents (1994). Their definition of ‘environmentally sensitive area’ is:

Marine and estuarine areas with high conservation, cultural (educational, recreational, historic, aesthetic) or economic values, and/or high vulnerability to environmental degradation as a result of natural disasters, pollution or over-exploitation of their resources.

3.2 Overview of Issues

The State of the Marine Environment Report (Zann, 1995, p. 90) highlighted a number of concerns about the condition of Australia’s coastal waters, in particular:

• declining quality of marine and coastal water and sediments, as a result of inappropriate catchment land use practices
• loss of marine and coastal habitat
• unsustainable use of marine and coastal resources
• lack of a marine science policy, and
• lack of strategic, integrated planning in the marine and coastal environments.

Their report pointed out that while the state of Australia’s marine environment is on average ‘good’, this was often not the case in the vicinity of urbanised areas. Their Report stated:

Estuaries and coastal waters near the State capitals are generally the most disturbed parts of the marine environment. Some parts of Sydney Harbour, Port Phillip Bay and the Derwent Estuary are so polluted by sewage, urban runoff, and industrial discharges that they are frequently closed for bathing and fishing. Zann (1995, p. 95)

The report did note, however, that:

Controls on discharges are showing signs of improvement. Zann (1995, p. 95)

Elevated levels of nutrients and sedimentation in coastal water bodies near urban areas are largely the result of inappropriate catchment land use practices, sewage discharges and urban runoff. Sediments alter estuaries and shores, and smother
sedentary marine life. Elevated nutrients cause eutrophication and the harmful
growth of algae. Blooms of blue-green algae are now common in many estuaries
and bays. Eutrophication is a serious threat to estuaries, temperate sea grass and
tropical corals. About a half of the sea grass in the estuaries of New South Wales
and the majority of seagrass in Westernport Bay in Victoria have been lost.
Tasmania, the South Australian Gulfs and south-western Western Australia have
all been locally affected. The loss of sub-tropical sea grass in Hervey Bay,
Queensland, has caused a serious decline in the dugong population.

Since European settlement, four times as much sediment, nitrogen and phos-
phorus now enter the Great Barrier Reef lagoon which extends from Cape York
to Bundaberg (Brodie, 1994). Sewage discharges contribute sediments and
nutrients to the Great Barrier Reef, causing localised problems, particularly
where there is no effective dilution of the treated effluent (Moss et al., 1992;
Steven and Brodie, 1994; van Woesik et al., 1990; Brodie, 1991). Sewage
discharges constitute a chronic stress. The Great Barrier Reef Marine Park’s
boundaries do not extend to the coastline along the western perimeter. Conse-
quently, some of the coastal cities’ ocean outfalls are outside the jurisdiction of

Marine pollution from heavy metals including mercury, cadmium and lead,
which are present in urban wastewaters, is a localised problem. ‘Hot spots’
include Lake Macquarie (NSW), Corio Bay (Vic), Derwent and Macquarie
Estuaries (Tas), and Port Pirie (SA).

Organochlorines or chlorinated compounds used as herbicides and insecticides in
agriculture and industry are toxic to marine life and are bioaccumulated in mar-
ine food chains. Local ‘hotspots’ include Sydney’s sewage outfalls, Homebush
Bay, Melbourne’s Port Phillip Bay sewage outfalls and Corio Bay.

Litter is a growing and conspicuous problem on some Australian beaches, in the
vicinity of urbanised areas. Litter reduces recreational and scenic values, and
may affect wildlife. Turtles and whales may die from eating plastic bags.

South eastern and south western coastal lakes, which have limited ocean water
exchange have been affected by terrestrial runoff. Significant losses of saltmarsh
and mangroves have occurred near urban areas through reclamations, drainage,
and other developments. This has affected fish and other sea life which use the
mangrove areas as nurseries and feeding grounds.

3.3 Projected Discharges of Wastewaters to Marine Environments

It is estimated from the National Effluent Re-use Survey, 1994 reported in this study,
that, in 1994, 1224 GL of treated sewage was discharged from town sewage treatment
plants to coastal waters in Australia. This includes discharges from all the larger sew-
age treatment plants in the coastal cities (Perth, Adelaide, Melbourne, Hobart, Darwin,
Sydney, Newcastle, Wollongong and Brisbane).
Current expectations are that the volume of sewage effluent discharged to coastal waters will increase by almost 50% to 1803 GL by the year 2020 (National Effluent Re-use Survey, 1994). The volume of discharges to coastal waters is expected to double in Western Australia in that period, while Queensland is also expecting a higher than average rate of increase in discharges to coastal waters. It is possible that water demand management will reduce the volume of wastewater discharged, as compared with the estimates in Table 1. However, the rate of growth of contaminant loads would not be affected, so the figures in Table 1 can be taken as broadly indicative of trends in future pollutant loads.

Table 1. Current and expected discharges of sewage effluent to coastal waters (including estuaries) 1994-2020 (GL/yr)

<table>
<thead>
<tr>
<th>Year</th>
<th>ACT</th>
<th>NSW</th>
<th>NT</th>
<th>Qld</th>
<th>SA</th>
<th>Tas</th>
<th>Vic</th>
<th>WA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>0</td>
<td>443</td>
<td>9</td>
<td>240</td>
<td>93</td>
<td>35</td>
<td>327</td>
<td>77</td>
<td>1224</td>
</tr>
<tr>
<td>2000</td>
<td>0</td>
<td>448</td>
<td>13</td>
<td>266</td>
<td>96</td>
<td>37</td>
<td>386</td>
<td>79</td>
<td>1325</td>
</tr>
<tr>
<td>2020</td>
<td>0</td>
<td>661</td>
<td>12</td>
<td>372</td>
<td>101</td>
<td>42</td>
<td>461</td>
<td>154</td>
<td>1803</td>
</tr>
</tbody>
</table>

Source: National Effluent Re-use Survey, 1994 (this report)

Sewage disposal practices have changed markedly over the past five years and further changes are being planned or evaluated. The “Clean Waterways” Program in NSW resulted in sludge being re-used rather than disposed to ocean, and the nearshore outfalls were replaced by deeper ocean outfalls. Environmental monitoring, engineering/ecological assessments and community consultation have been undertaken in Perth and south west Western Australia (Perth Coastal Waters Study, Geographe Bay Study, Wastewater 2040); Brisbane (Moreton Bay Study), Adelaide (Gulf of St Vincent) and Melbourne (Port Phillip Bay). South Australia is evaluating re-use possibilities for effluent from the Bolivar treatment plant in Adelaide. Both Hobart and Darwin have moved towards greater re-use as a result of environmental considerations.

In comparison with our knowledge of wastewater flows, comparatively little is known about the volumes and quality of stormwater discharging from our towns and metropolitan areas to estuarine and coastal waters. Most attention by engineers and researchers has been on flood estimation procedures, for use in the design of drains, setback areas, roads, bridges and flood-control devices. The standard text is Australian Rainfall and Runoff (Pilgrim, 1991). Until recently, little attention has been given to the pollutant characteristics of urban stormwater. Thus, it is not possible to be precise about the level and quality of stormwater discharges to receiving waters from urban areas in Australia.

The data given in Table 2 are indicative of the broad magnitudes of mean annual runoff and discharges of sewage from coastal metropolitan areas.

The data in Table 2 need to be interpreted with caution, as the figures for runoff include flows from semi-rural and rural areas. The Sydney-St Georges River Basin provides an example where the whole basin is highly urbanised, and mean annual runoff is similar in magnitude to the volume of sewage discharged. Thus, in Sydney, if stormwater pollutant concentrations are similar (or worse) than those in sewage effluents, then the stormwater will be contributing a similar (or greater) pollutant load as (than) the sewerage system. Brisbane and Melbourne on the other hand, each have a
Table 2. Comparison of stormwater runoff volumes with sewage discharges: selected coastal cities (GL)

<table>
<thead>
<tr>
<th>City</th>
<th>Water Basins (and basin codes)</th>
<th>Mean Annual Runoff (1)</th>
<th>Sewage Discharges (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brisbane</td>
<td>Brisbane (143) and Pine Rivers (142)</td>
<td>1860</td>
<td>113</td>
</tr>
<tr>
<td>Sydney</td>
<td>Sydney/St Georges River (213)</td>
<td>500</td>
<td>424</td>
</tr>
<tr>
<td>Melbourne</td>
<td>Bunyip (228), Yarra (229), Maribyrnong (230) and Werribee (231) Rivers</td>
<td>1650</td>
<td>340</td>
</tr>
<tr>
<td>Adelaide</td>
<td>Myponga (502), Onkaparinga (503), Torrens (504) and Gawler (505) Rivers</td>
<td>306</td>
<td>183</td>
</tr>
</tbody>
</table>

(1) Water basins and mean annual runoff are taken from the 1985 Review of Australia’s Water Resources and Water Use (Department of Primary Industries and Energy, 1987). The numbers in brackets are the basin codes.
(2) Sewage discharges are taken from the National Effluent Re-use Survey, 1994 (this report).

large river flowing through the city, with catchments that go well into their hinterlands. For these rivers, while urban pollution loads will be similar to other cities, pollutant concentrations in local rivers and streams may differ considerably from those typical of urban stormwater. The pollutants generated in the rural parts of the catchment, need to be taken into account in assessing strategies for the abatement of impacts on receiving waters.

As urban development proceeds, and the average permeability of the land surface is diminished by the construction of roads, paved areas and buildings, urban runoff increases. The growth of population, industrial activity and consumption per head also increases the amount of wastes generated. Thus both total stormwater flows and total pollutant loads increase. Data from South Australia, given in Part IV, Table 38 suggest that stormwater may be as badly contaminated as primary-treated sewage effluent in terms of biochemical oxygen demand, oils and greases, bacteria, phosphorus, total nitrogen and heavy metals; and distinctly worse in quality than the secondary-treated effluent which is the general standard in most Australian metropolitan sewage treatment plants. Given that coastal aquatic ecosystems in Australia are commonly nitrogen-limited it is relevant to note that total nitrogen concentration of urban stormwaters may be equivalent to, or may well exceed, that of secondary-treated sewage effluent. Data for Port Phillip Bay suggest that discharges of toxic metals such as cadmium, copper, chromium, lead, mercury, nickel and zinc from rivers and drains exceed the loads generated by the Werribee Treatment Plant by a factor of 2–10.

3.4 Coastal Water Quality Protection Policies

Responsibility for protection of coastal environments is shared between the Commonwealth and the States and Territories. A number of steps have been taken:

- A recommendation of the Coastal Zone Inquiry (1993) was the adoption of a National Coastal Action Program (NCAP) by COAG, to be implemented
by all three levels of government in consultation with industry and community groups. This is currently being discussed within the COAG framework.

- The principal aims of the NCAP are:
  - reduced degradation from urban sprawl and related activities
  - more effective and rational land use in coastal catchments
  - improved water quality in streams, estuaries and coastal seas
  - improved recreational facilities in the coastal zone
  - better management of natural processes, and
  - improved fisheries management.

- Marine parks have been proclaimed: these incorporate zones which permit activities appropriate to the conservation value and sensitivity of each area. This model is used, with local variations, by the Commonwealth (Great Barrier Reef Marine Park), NT, NSW, Vic, and WA.

- Systems of water quality protection for specific uses are used in SA, Vic, and NSW. WA uses a system based on a draft modification of National Water Quality Management Strategy (1992) guidelines on water quality.


- Catchment management programs are underway in some parts of Australia to reduce soil erosion and discharge of nutrients. However, these are mainly focussed on rural catchments, and progress in implementing urban catchment management reforms has so far been slow and patchy.

- Most states have reviewed the impacts of sewage effluent discharges and in some cases this has led to modification of practices. In New South Wales and Queensland, policies have been implemented to upgrade the quality of treated sewage effluents being discharged to coastal receiving waters. South Australia has been investigating, and is about to implement, options for land disposal of Adelaide effluent. Victoria has been examining the impacts of the Werribee STP on Port Phillip Bay. New studies are underway to review methods for alleviating potential impacts of effluent discharged to Bass Strait from the South East Purification Plant. The studies will include potential wastewater re-use. Western Australia has completed the Perth Coastal Waters Study (Simpson et al., 1993), and has adopted a policy of monitoring coastal waters, while continuing with its marine disposal strategy. The Northern Territory government is proceeding with some re-use of treated effluent in Darwin.

- The National Water Quality Management Strategy will provide a general framework of guidelines for water quality management in the coastal zone.

- The Commonwealth Government has recently commenced a National State of the Environment Reporting Program based on a pressure-state-response model. It is intended that a national set of environmental indicators be developed for future quantitative reporting (CEPA, 1993).
It is suggested that improved wastewater and stormwater management can help in addressing:

- declining quality of marine and coastal water and sediments, particularly as a result of inappropriate catchment land use practices
- loss of marine and coastal habitat
- unsustainable use of marine and coastal resources, and
- lack of strategic, integrated planning in the marine and coastal environments.

4. DISCHARGE OF WASTEWATERS TO INLAND/FRESH WATERS

4.1 Overview

Australia’s rivers are subject to many environmental problems, including increased nutrient levels and changed flow regimes. Concerns about the state of our inland waterways have been exacerbated since the world’s largest outbreak of toxic blue-green algae in the Murray Darling System in 1990-1991. Appendix B gives cases of disposal of wastewaters to inland waters in Australia.

Due to their temporal distribution, wastewater flows may have an influence which is disproportionate to their volume. Wastewater flows are relatively constant within and across years while flow rates in inland rivers vary significantly with the season and from year to year. Nutrients from wastewater may not be a major part of the overall nutrient load in a river whose normal flow is dominated by agricultural runoff, except during low flow periods. It is during these low flow periods, when nutrient concentrations are highest, that algal problems are most likely to occur. Re-use systems for water that is currently discharged to inland rivers must be sensitive to these issues. Re-use schemes will typically lead to a reduction both in nutrient levels and total water volume discharged to the river. While the reduction in nutrient levels would generally be environmentally beneficial, the reduction in flow may be detrimental.

Settlements within the Murray-Darling Basin in Queensland, New South Wales, Canberra, Victoria and South Australia have either been upgrading treatment levels to reduce nutrient loads entering the river (for example: Toowoomba which was the biggest contributor of nutrients to the river systems in Queensland), disposing to land or to woodlots (many SA country towns have taken this approach), or storing treated effluent on land and discharging at peak flow times. Prolonged drought conditions have also forced water authorities, consumers and local councils to consider re-use as a supplementary supply source.

Programs addressing nutrient inputs have also been established for other basins. Sydney Water Corporation has been working on reducing nutrient inputs into the Hawkesbury-Nepean through infill sewerage programs and the upgrading of treatment levels. The New South Wales EPA now requires environmental impact assessment of all sewage treatment plants in the Hawkesbury-Nepean System.
4.2 Murray-Darling Basin

Many of the inland waterways of Australia that receive town wastewater discharges fall within the Murray-Darling Basin.

In response to rising concern at the level of nutrients and eutrophication, the Murray-Darling Basin Commission has established a nutrient management strategy. A study conducted in 1991 (Gutteridge, Haskins and Davey, 1992) concluded that over 70% of dry weather nutrient loads from point sources originated from effluent discharges. The study estimated that approximately 500 tonnes of total phosphorus were discharged annually to main stream rivers from sewage treatment plants in the Basin, and an estimated 2800 tonnes of total nitrogen. These discharges were considerably greater than the estimated dry weather discharges of total phosphorus and total nitrogen from irrigation drains, and from urban stormwater.

The above estimates exclude the nutrients supplied to the Basin’s river systems by intensive rural industries (feedlots, abattoirs, dairy processors, fruit and vegetable processors and wineries). They also exclude the effects of redistribution of nutrients within watercourses. Aeolian sources and direct animal contributions may also be significant, particularly in dry years.

In wet years the mass of nutrients discharged from town sewage treatment plants remains the same, but the discharges from irrigation drainage and urban stormwaters increases. Nevertheless, even in wet years, sewage treatment plants account for about a half of the estimated nutrient flow from point sources.

In 1992, a Blue-Green Algae Taskforce considered control actions, including the reduced nutrient discharges from sewage treatment plants. These recommendations were implemented in the Algal Management Strategy, 1994. In 1994–5 a broad-ranging study was commissioned to:

- determine exactly where nutrients and sediments are generated within a large sub-catchment containing natural and agricultural land uses
- identify processes of nutrient and sediment loss, and
- develop a model and management practices that can be applied at catchment scale.

The Algal Management Strategy seeks to:

- reduce nutrient concentrations in the streams and storages of the basin
- improve stream-flow regimes and flow management
- increase the community’s awareness of the blue-green algal problem, and
- obtain better information and scientific knowledge of blue-green algae.

4.3 Hawkesbury-Nepean River Basin

The amount of phosphorus and other nutrients has become a serious problem in the Hawkesbury-Nepean River Basin. The problem is due largely to the di-
version of natural streamflows in order to supply water to Sydney, Illawarra and Blue Mountains regions, and irrigation. Discharges of sewage effluent and nutrients from other sources have been a concern. Managing water quality will become more difficult in future with increasing urbanisation and other development.

Effluent discharges from sewage treatment plants dominate the flow during dry weather. In wet weather, diffuse nutrient sources, including agriculture, and runoff from urban areas dominate. While Sydney Water has invested in upgrading the treatment plants, the incremental costs are very high. Treatment plant upgrades in themselves may not be sufficient to deal with nutrient pollution. A study commissioned by the NSW EPA (James et al., 1994) has indicated that to have a significant impact on cost savings and economic efficiency in controlling nutrient inputs, non-point sources would have to be brought into any institutional solution.

4.4 Projected Discharges

Currently, 295 GL of sewage is discharged annually to Australia’s inland and fresh waterways after varying degrees of treatment. Generally, the metropolitan water utilities apply higher levels of treatment in those plants discharging to inland waters, but the degree of treatment varies substantially among the smaller towns.

The volume of treated sewage expected to be discharged to inland/fresh waters by wastewater utilities is expected to increase by 30% to 381 GL in the year 2020. However results of the National Effluent Re-use Survey indicate that the ACT, New South Wales and Queensland would have higher than average rates of growth in volumes discharged to inland/fresh waters (45, 70 and 55% growth, respectively). The Northern Territory, South Australia, Victoria and Western Australia expect to have static or declining discharges to inland/fresh waters. Victoria is aiming for a significant reduction.

Table 3. Current and expected discharges of sewage effluent to inland/fresh waters (including estuaries) 1994–2020 (GL/yr)

<table>
<thead>
<tr>
<th></th>
<th>ACT</th>
<th>NSW</th>
<th>NT</th>
<th>Qld</th>
<th>SA</th>
<th>Tas</th>
<th>Vic</th>
<th>WA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>33</td>
<td>138</td>
<td>1</td>
<td>32</td>
<td>2</td>
<td>14</td>
<td>74</td>
<td>1</td>
<td>295</td>
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<tr>
<td>2000</td>
<td>38</td>
<td>158</td>
<td>1</td>
<td>35</td>
<td>2</td>
<td>15</td>
<td>46</td>
<td>0</td>
<td>295</td>
</tr>
<tr>
<td>2020</td>
<td>48</td>
<td>234</td>
<td>1</td>
<td>49</td>
<td>2</td>
<td>17</td>
<td>30</td>
<td>0</td>
<td>381</td>
</tr>
</tbody>
</table>


Little is known about the volumes or quality of town stormwater discharges to inland waterways, though urbanisation in the Murray-Darling and Hawkesbury-Nepean River Basins and in South-east Queensland is expected to increase both flows and pollutant loads.

Table 4 shows that the inland waters into which sewage is discharged, currently support a wide variety of environmental values (identified as ‘beneficial uses’ in the National Effluent Re-use Survey). In Victoria and New South Wales, in particular, the
Table 4. Beneficial uses of waters receiving discharges of sewage effluent, (by state)

<table>
<thead>
<tr>
<th>Beneficial Use</th>
<th>ACT</th>
<th>NSW</th>
<th>NT</th>
<th>Qld</th>
<th>SA</th>
<th>Tas</th>
<th>Vic</th>
<th>WA</th>
<th>Total</th>
<th>% rounded</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At Present</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Irrigated agriculture</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>Urban water supply</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>Recreation, fishing, boating etc</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>Commerce, tourism</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>Protection of aquatic environments</td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td></td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Other conservation</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>6</td>
</tr>
<tr>
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<td></td>
<td>1</td>
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<td></td>
<td>2</td>
<td>6</td>
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<tr>
<td>Other</td>
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<td></td>
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<td></td>
<td></td>
<td>1</td>
<td></td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>5</td>
<td>8</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>8</td>
<td>2</td>
<td>31</td>
<td>100</td>
</tr>
</tbody>
</table>

| **Future Purposes**             |     |     |    |     |    |     |     |     |       |           |
| Irrigated agriculture           | 1   | 1   | 1  | 1   | 1  | 1   |     |     | 5     | 16        |
| Urban water supply              | 1   | 1   | 1  | 1   | 1  | 1   |     |     | 5     | 16        |
| Recreation, fishing, boating etc| 1   | 1   | 1  | 1   | 1  | 1   |     |     | 5     | 16        |
| Commerce, tourism               | 1   | 1   | 1  | 1   | 1  |     | 1   |     | 5     | 16        |
| Protection of aquatic environment | 1  | 1   |    | 1   |    | 1   | 1   |     | 4     | 14        |
| Other conservation              | 1   |     |    | 1   |    |     |     |     | 2     | 6         |
| Industrial purposes             | 1   |     |    |     |    | 1   |     |     | 2     | 6         |
| Other                           |     |     |    |     |    | 1   |     |     | 2     | 6         |
| **TOTAL**                       | 5   | 8   | 3  | 4   | 2  | 0   | 8   | 0   | 30    | 100       |

1 denotes the existence of the particular use

Full range of beneficial uses listed in the Table is active within the waterways receiving sewage discharges.

In some cases it is not appropriate (from an environmental viewpoint) to dispose of effluent on land if:

- groundwater is close to the surface and land disposal may result in water logging
- the practice may result in contamination of groundwater, and
- land disposal may lead to problems with soil salinity or sodicity.

In other cases climate or land area requirements (both for storage and disposal purposes) may limit the potential for land disposal. Therefore, cost should not be the only factor influencing decisions on the management of effluent.

In line with recommendations in the 1994 Algal Management Strategy for the Murray-Darling Basin, discharges to inland waters should be managed to:

- control nutrient concentrations in receiving waters, and
- improve stream-flow regimes and flow management.
Re-use and land application systems should be implemented where appropriate and cost effective.

- Where cost-effective, practical and environmentally sustainable land-based disposal systems should be adopted ahead of enhanced nutrient removal processes or the continued discharge to sensitive water environments. Where land-based treatment is not economically viable, plants need to be upgraded. Water quality monitoring programs should be enforced where discharge to water bodies will continue in the future.
- Increasing urbanisation and other developments should be monitored to ensure that the amount of phosphorus and other nutrients, which has become a serious problem in many urban areas, is not exacerbated.

To summarise, aquatic environmental considerations generally favour increased treatment levels and reduced discharge of nutrients, pathogens and toxics. If treatment and management are upgraded, the wastewater will be more suitable for re-use in some form. The twin objectives of using wastewaters as a resource and improving the environment are generally complementary.

In some situations, environmental considerations may favour conventional approaches and continued discharge. In many cases the environmental desirability of improved discharge practices may be agreed but re-use of treated sewage or increased expenditure on stormwater management may be considered to be economically not feasible.

5. INSTITUTIONAL AND REGULATORY FRAMEWORK

5.1 Overview

Throughout Australia there have been rapid changes in institutional arrangements for water resources and environmental management. These have generally tended to separate the powers and responsibilities of water utilities from those of government departments dealing with planning, resource management and environmental protection.

Changing institutional demarcations and roles raises a number of issues about the ownership and transferability of wastewater. For example, it is not always clear whether a corporatised or privatised wastewater utility actually owns the sewage that it transports and treats. Generally, however, corporatisation or privatisation of utilities is consistent with the development of re-use projects. Most re-use projects in the USA are operated by such utilities within a framework of government regulation. The situation is more complicated, however, with respect to stormwater.

5.2 Institutional Roles and Responsibilities for Stormwater Management

As implementation of the National Water Reform Agenda proceeds, new institutional roles and responsibilities will be required to take care of urban stormwater management. The water utilities increasingly concentrate on their core business of water supply and sewerage, relying on ‘whole of government’ or community approaches to deal with stormwater issues. What form the institutional response should take is a matter for individual governments. Several jurisdictions are changing their water legislation to redefine institutional powers and responsibilities in the
stormwater area, including catchment management. Part III of this report addresses these issues.

5.3 The National Water Quality Management Strategy

The basic regulatory framework for control of discharges is at state level, within guidelines established by the National Water Quality Management Strategy (NWQMS). This has been developed jointly by the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and the Australian and New Zealand Environment and Conservation Council (ANZECC). The National Health and Medical Research Council (NHMRC) is involved in aspects of the NWQMS which affect public health. The philosophies and policies of the NWQMS are set out in the paper titled Water Quality Management – An Outline of the Policies, and an accompanying document, Policies and principles – A Reference Document, (National Water Quality Management Strategy 1994).

Management of water resources is recognised as a State and Territory responsibility, and it is proposed that the NWQMS would be implemented after considering State and Territory water policies, as well as the National Guidelines. The NWQMS uses the concept of environmental values to set local water quality targets established in partnership with the community and government. Environmental values may be distinguished from the concept of beneficial use in that the former is derived explicitly by reference to community input, rather than being assigned directly by a planning or regulatory authority based on current uses.

The NWQMS is expressed in 20 documents. The following are of special relevance for this study:


In contrast to the National Water Quality Management Strategy Guideline documents, which are essentially manuals for practitioners, this report focuses on the ramifications of the COAG Water Reform Agenda. This report makes references to the Guideline documents, and recommendations about their content are made in places.
The strategic framework for reform of the Australian wastewater sector should involve environmentally sustainable management of wastewater and stormwater from metropolitan and town water services. Specifically, an improved quality of natural environment needs to be sustained in urban regions, including the marine environment of coastal cities, and the riverine or lacustrine environments of inland cities and towns.

Future wastewater re-use systems should satisfy environmental objectives, including: the need for clean beaches, rivers and streams; improved sewage treatment to ensure safe, beneficial or environmentally acceptable disposal of effluent; cost-effective protection from sewage overflows, improved sewage treatment plant reliability; safe beneficial use or environmentally acceptable disposal of treated residuals; stormwater pollution source control, waste minimisation and recycling sewage by-products.
PART II:

RE-USE OF WASTEWATERS
PART II: RE-USE OF WASTEWATERS

This part of the report considers the current and future status of wastewater re-use projects in Australia and overseas. The first section below cites the principal reasons for undertaking re-use projects. Section 9 provides a review of public acceptability and health issues. Section 10 discusses the economics of wastewater re-use and gives examples of re-use projects in Australia and internationally (outlining in each case the nature of benefits, the problems encountered and issues to be resolved).

Section 11 discusses the current and planned re-use of treated sewage in Australia and presents the results of the National Effluent Re-use Survey, 1994. This survey was conducted by Melbourne Water on behalf of the Water Technology Committee in late 1994 and evaluated by CSIRO. Included in this section is a discussion on national re-use trends and predictions between 1994 and the year 2020.

Finally, Section 12 considers whether special consideration needs to be given to water reclamation and re-use in the context of economic, institutional, market, regulatory and pricing reforms instigated by the COAG National Water Reform Agenda.

6. REASONS FOR RE-USE

The main motivations for wastewater re-use schemes are:

- to supplement limited primary water sources and to help prevent excessive diversion of water from alternative uses, including the natural environment
- as a method of managing in-situ water resources
- to minimise costs, including total treatment and discharge costs
- to reduce or eliminate discharges of treated sewage to receiving waters, and
- because of political or institutional constraints.

6.1 Supplementary Supply

Internationally, most large-scale re-use schemes are in arid/dry climatic locations - e.g. Israel, South Africa and arid areas of the USA, where alternative sources of water are limited. Even if rainfall is adequate it may not be available at the correct place or time. For example Florida, while it is not a dry area in general, has limited options for water storage, and suffers from water shortages during dry spells. For this reason water re-use schemes form an important part of the water supply system. In 1992 Florida had 308 wastewater treatment plants producing reclaimed water. They delivered a total of 481 ML/yr) of reclaimed water to 295 re-use systems. The output of reclaimed water is expected to double in the near future (Florida Department of Environmental Protection, 1991).
6.2 Resource Management

Re-use can be a method of water resources management. For example, depleted aquifers may be ‘topped up’ by injection of reclaimed water, in order to restore aquifer yields or prevent seawater intrusion, as is done in California and Florida.

6.3 Cost Minimisation

High costs associated with conventional water supply or wastewater disposal may make re-use attractive. For example, many high-rise buildings in Japan contain water recycling systems. These buildings are served by sewers which were originally designed for a lower level of wastewater flow and one of the major advantages of re-use is in postponing the cost of sewerage upgrades (Kiya and Aya, 1991). Other possible cost influences on re-use are increasing pollution of alternative sources (leading to increased treatment costs) and potential reductions of the costs of headworks and distribution systems where re-use is practiced.

6.4 Environmental Protection

The discharge of inadequately treated wastewater may lead to environmental problems, as discussed in Part I, and this may encourage re-use. While the nutrients in wastewater can assist plant growth, they can be detrimental to ecosystems and contribute to algal blooms in rivers and estuaries. In addition there may be concern about the level of heavy metals in wastewater. The volume of wastewater flow may have environmental consequences, both in raising watertables and increasing flow rates in rivers. This may be more significant in low periods. As already noted, wastewater discharge may be beneficial if low flows are due to upstream diversions.

6.5 Political/Institutional Constraints

Concerns about water supply or environmental pollution may emerge as political or as institutional constraints. Community concern about the quality of wastewater disposed to sensitive environments may lead to political pressures to treat wastewater to a higher level. The regulatory framework applying to wastewater disposal and re-use reflects these concerns and includes: wastewater discharge licensing by the Federal and State Environmental Protection Agency/Authorities; health legislation to protect people from waterborne diseases; water legislation; and standards, criteria and guidelines for wastewater disposal and re-use categories (at a national level via the National Water Quality Management Strategy, and on a State/Municipal level for local conditions). In the USA, a major reason why utilities have chosen wastewater reclamation was that the alternative course, of seeking a discharge permit under the National Pollution Discharge Elimination Scheme (NPDES), was seen as being more risky to the utility and/or more costly.

Institutional structures may also provide incentives for re-use. As responsibility for different parts of the water use and disposal system may rest with different organisations, a water utility may also be faced with standards of service set in agreements
with other industry bodies. The restructuring currently taking place in the water industry in Australia increases the importance of clearly defining institutional responsibility for particular non-utility aspects of service delivery (for example, stormwater and drainage), performance monitoring, environmental policy, water resource management and community participation.

It is usually a combination of these factors which causes a re-use scheme to get off the ground. An example is the St Petersburg re-use scheme in Florida, USA. The scheme is claimed to be the largest in the world, with reclaimed water output of 26 Mgal/d (118 ML/d). Key features of this scheme are as follows:

- Motives for the scheme were two-fold: (i) a shortage of cost-efficient, divertible water sources in the region of St Petersburg, and (ii) determination to undertake a clean-up of the polluted waters of Tampa Sound, on the Gulf of Mexico.
- Influent comes from a separate sewer system, dominated by residential sewage inputs.
- The treatment train is (i) grit removal, (ii) aeration, (iii) clarification, (iv) multimedia filtration, chlorine contact basin, and (v) effluent storage. No attempt is made to remove nutrients. However the advanced treatment can handle all expected hydraulic and organic loadings, with both chemical treatment and filtration.
- There is continuous, remote monitoring of the treatment processes, including both hydraulics and water quality, with 24 hrs/day, 7 days/week effluent sampling, and continuous surveillance by qualified operators.
- The reclaimed water is supplied to (i) spray irrigation sites, all of which overlay a brackish non-potable aquifer; and (ii) deep injection wells, which have been installed to deal with saline intrusion problems. A distribution network for the reclaimed water has some 300 km of pipes, extending over most of the metropolitan region of St Petersburg. However, there was relatively little retro-fitting, as the city’s population has been growing rapidly, and mainly new developments were supplied by the reclaimed water system.
- Approximately 40% of the total public water supply in 1994 came from the re-use system.
- Unit production costs are not available, but benefits of the reclaimed water scheme are said to include: avoidance of more expensive long-distance piped supplies or desalination plants; avoidance of a capacity expansion for a lime softening plant; and avoidance of a third trunk transmission line for potable water.
- While epidemiological studies have been inconclusive, considerable attention has been paid to public health aspects.

All Australian jurisdictions should recognise that water re-use is a viable and attractive alternative source of water supply, which may contribute to the abatement of environmental problems associated with fresh water diversions or the discharge of polluted effluents to receiving waters.
The potential for re-use schemes should be assessed
• to augment limited primary water sources
• to help prevent excessive diversion of water from alternative uses, including the natural environment
• as a method of managing in-situ water resources
• to minimise infrastructure costs, including total treatment and discharge costs
• to reduce or eliminate discharges of treated sewage to receiving waters
• to satisfy political, community and institutional constraints, and
• to reduce stormwater pollutant loads to receiving waters.

7. TREATMENT METHODS

The methods and degree of treatment required for water re-use differ according to the hydraulic and bio-chemical characteristics of the wastewater, and the potential end uses. James et al., (1994), lists four additional levels of treatment required in a conventional municipal activated sludge plant corresponding to reclamation for various uses. The end uses considered were:

A: agricultural irrigation, dust suppression and quenching
B: urban irrigation and cooling towers
C: residential non-potable, boiler feed and cooling towers; and
D: indirect potable.

The critical treatment processes for each of the above, which are very common in re-use schemes throughout the world, are in ascending level of treatment:
• A = primary biological reactor, secondary clarifiers, and disinfection
• B = A + biological nutrient removal and filtration
• C = B + flocculation/coagulation
• D = C + tertiary clarifiers, pre-chlorination, microfiltration, and reverse osmosis.

Microfiltration is often considered as an alternative to reverse osmosis as a final polishing treatment, but there are also small-scale micro-filtration package plants which offer a complete treatment train.

A number of different treatment and disposal or reuse alternatives are usually available, depending on the degree of treatment required. Contaminants in wastewater are removed by physical, chemical and biological means. Treatment systems used to remove major contaminants found in wastewater are summarised in Table 5. A more detailed discussion of these operations and processes are presented in Tchobanoglous and Burton (1991). More advanced wastewater treatment operations and processes are shown in Table 6.

Some industrial markets for reclaimed water require specific water quality, in particular low total dissolved solids content. The trading arm of Sydney Water, Australian Water Technologies, is refining its product mix to match desired quality in various re-use markets. In particular, a compact ‘sewer mining’ system allows raw sewage to be extracted directly from pipes for processing (the Aqua Re-use System).
A large variety of household-level treatment devices is available. These have been approved by public health authorities, especially for use in areas without sewerage, and where the on-site treatment and re-use of household wastewater may be preferable to disposal via septic tanks. A Perth Seminar on Urban Wastewater Re-use (Australian Institute of Urban Studies, 1993) provides an account of alternative small-scale systems. The proceedings of a symposium held at Murdoch University in 1995 goes into greater technical detail on the performance of small-scale systems (Jeppesen, 1994).

The NWQMS Guidelines for Sewerage Systems: Use of Reclaimed Water (National Water Quality Management Strategy, 1996a) is the most up-to-date document on recommended water quality for re-use water in Australia. The United States Environmental Protection Agency (US EPA) document “Guidelines for Wastewater Re-use” (Camp, Dresser and McKee, 1992) provides a wide-ranging review of the subject from an international perspective.

Much has been said (but little has been written) on the relationship between re-use potential and the size of the water supply-sewerage network. Judging from international experience there is potential for re-use at all system scales, from the household level to the large integrated metropolitan systems. For example, California has an active re-use program which is being grafted onto an ever more integrated state-wide pipe network. Re-use has advantages and disadvantages at each level. The choice is conventionally a technical and economic one, though some view it as important that the community as a whole should become more involved in the working of the system and they favour more decentralised approaches.
<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Unit operation, unit process, treatment system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Suspended solids</strong></td>
<td>Screening and comminution</td>
</tr>
<tr>
<td><strong>Biodegradable organics</strong></td>
<td>Activated-sludge variations</td>
</tr>
<tr>
<td><strong>Volatile organics</strong></td>
<td>Air stripping</td>
</tr>
<tr>
<td><strong>Pathogens</strong></td>
<td>Chlorination</td>
</tr>
<tr>
<td><strong>Nutrients:</strong></td>
<td>Suspended-growth nitrification and denitrification variations</td>
</tr>
<tr>
<td><em>Nitrogen</em></td>
<td>Metal-salt addition</td>
</tr>
<tr>
<td><em>Phosphorus</em></td>
<td>Biological nutrient removal</td>
</tr>
<tr>
<td><strong>Nitrogen and Phosphorus</strong></td>
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<td><strong>Refractory organics</strong></td>
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<td><strong>Dissolved organic solids</strong></td>
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<th>Principal removal function</th>
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<td>Microstrainers</td>
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<td>Ammonia oxidation</td>
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<td>Nitrogen removal</td>
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<td>Combined nitrogen and phosphorus removal by biological methods</td>
<td>Biological nitrification/denitrification and phosphorus removal</td>
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<td>Nitrogen removal by physical or chemical methods</td>
<td>Air stripping</td>
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<td>Phosphorus removal by chemical addition</td>
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<td>Toxic compounds and refractory organics removal</td>
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<td>Volatile organic compounds</td>
<td>Volatilisation and gas stripping</td>
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Figure 1 shows the treatment level practices in each state in 1994, from the National Effluent Re-use Survey. In general, secondary treatment is the most common level, although it is notable that in many states, primary treatment accounts for a small proportion of the total, except New South Wales, where 60% was treated to primary level only. Victoria (Melbourne) and the ACT are the two urban areas with high levels of tertiary treatment.

![Treatment levels (by state) – 1994](image)

Figure 2 shows disinfection methods practiced in each state in 1994, from the National Effluent Re-use Survey. It is evident from this Figure, that disinfection methods differ between states, and that in New South Wales and Western Australia, a high proportion of effluent is not disinfected.
8. USES FOR RECLAIMED WATER

There are many uses to which reclaimed water may be put. They may be summarised as follows:

- irrigation of woodlots, crops or pastures
- irrigation of urban landscapes and recreation areas
- non-potable residential uses, including both domestic level re-use and dual reticulation schemes
- residential potable re-use
- industrial/commercial, including re-use within treatment plants
- groundwater management, and
- surface water management, including aquaculture and mariculture.
The following sections provide an overview and examples of each of the above. Appendix C gives a listing of re-use schemes derived from the literature survey and industry consultation process.

8.1 Irrigation of Woodlots, Crops and Pastures

The potential exists for wastewater to be used as a source of irrigation water for woodlots, crops and pastures. Eden (1994) has identified seven agricultural or silvicultural activities where reclaimed water can be applied, namely: woodlots, turf farms, vineyards, vegetables (restricted), hydroponics, cut-flowers and ornamental trees, and plant nurseries.

Myers et al., (1995) provide an overview of planning, design and monitoring requirements for forestry plantations irrigated with effluent, based on trials near Wagga Wagga, NSW.

Wastewater may be a preferred option for irrigation of agricultural crops because the nutrients in it may reduce the need for other fertilisation. However, this may not eliminate the need for specific treatment. If the nutrient level is too high then it may be necessary to limit the amount of re-used water applied in order to avoid fungal problems. Contamination by heavy metal or other pollutants may be detrimental to crops. The creation of anaerobic conditions in the soil following sustained application of reclaimed water with significant biological oxygen demand (BOD) content can cause problems with odour and plant function. High levels of chlorine in treated water may also make water unsuitable for irrigation.

If the salinity level of the effluent is too high then it becomes unsuitable for many crops. Treatment processes such as stabilisation lagoons, where total salinity of the effluent is likely to increase, may need to be replaced by settlement, sand filtration and ultra-violet disinfection prior to irrigation onto crops.

Health requirements affect the required water treatment levels for various crop types, based on the likelihood of human contact with the wastewater. For example, Victorian regulations divide wastewater into different grades, depending on the treatment they have received. Category One wastewater (primary treatment only) can be used on fibre or seed crops, fodder crops for animals other than pigs, beef cattle and milking animals, and forestry areas or tree nurseries with no public access. Category Two wastewater (secondary treatment) may be used to irrigate food crops that are cooked, peeled or processed before eaten, pasture and fodder crops for animals excluding pigs, cattle and milking animals, as well as orchard and vineyard crops (Eden, 1994).

Health requirements also affect what kind of irrigation techniques may be used. Drip or underground irrigation schemes have a reduced risk of human contact or ingestion as compared to spray or sprinkler based systems, and so can be used with water of a lower quality.

Potential health and environmental effects may result from impurities in effluent including nutrients, pathogens (bacteria and viruses) and toxic substances. After
disposal, a number of outcomes may result, with respect to these impurities (Water Authority of Western Australia, 1994):

- they may be destroyed (for example, bacteria and viruses may die over time)
- impurities such as salts, phosphorus and heavy metals may be retained in the soil and may cause future salinisation, land degradation or the need for soil replacement strategies
- they may be taken up by vegetation;
- they may remain in water run-off, leading to nutrient build-up in lakes and rivers, and
- they may infiltrate groundwater, also leading to nutrient and salt build-up and other potential problems. The response time for groundwater contamination will depend on the depth of the water table and transmissivity of the unsaturated zone. Groundwater discharge is often a source of flow in rivers, particularly during dry seasons.

The effects of land disposal differ across sites, depending on climate, topography, soil characteristics (type, drainage, depth), geological formations, hydrogeology, land use and proximity to dwellings and watercourses.

In common with other re-use schemes, agricultural re-use schemes reduce the volume of wastewater discharged directly to the aquatic environment. Because the irrigated crops will take up some of the nutrient in the water, the levels of nutrient reaching natural waterways may also be reduced.

### 8.2 Irrigation of Landscape and Recreational Areas

Irrigation of urban landscape and recreational areas is one of the most common applications of wastewater world-wide, with examples being found in the USA, Mexico, Japan and Arabia. Municipal authorities throughout Australia have used treated wastewater for irrigation of recreational areas for decades.

The wastewater may be used to irrigate public parks, golf courses, ovals and other sporting facilities or to create recreational water bodies in parks. The creation of surface water bodies may be a way to cope with excess flows during periods of reduced demand for reclaimed water. However, because the water is used in areas that are open to the public, there is potential for human contact; consequently re-use water must be treated to a high level to avoid risk of spreading disease. Schemes must be managed effectively to avoid problems with community health, aesthetics, odour, insect infestation and the build up of nutrients, including eutrophication and algal blooms.

The demand for irrigation water is seasonal, and limited by the amount of land to be irrigated. Parks and recreation areas tend to be scattered and, individually, are relatively small water users. The difficulty and expense of providing reticulation may be a barrier to many of these schemes. Nevertheless, such schemes have the potential to improve the amenity of the urban environment and reduce the demand for new source developments. They also reduce the total wastewater flows to the environment and,
because there is some nutrient uptake by the plants, reduce the release of nutrients into the aquatic environment.

8.3 Non-Potable Residential Re-use

Non-potable, residential re-use schemes comprise local systems, (that is: systems operating in a single house or building complex), and dual reticulation systems.

8.3.1 Local Systems

Domestic wastewater can be separated into two flows: ‘greywater’ and ‘blackwater’ (ACT Electricity and Water, 1994a). Greywater is all liquid waste originating from a domestic dwelling with the exception of toilet and bidet waste, which is known as blackwater (ACT Electricity and Water, 1994a, 1994b). While greywater does not have the level of faecal contamination of blackwater, the levels of faecal coliforms and other bacteria in some sources of greywater means that it is generally not suitable for uses where human contact is possible.

Non-potable greywater re-use schemes may treat the water to a primary level, or a higher level, including some filtration and disinfection. Water quality studies suggest that untreated and primary treated greywater frequently contains levels of faecal coliforms and other bacteria which make it unsuitable for use as contact water. This includes uses such as toilet flushing where, although there is no intended human contact, the spray created by a flushing toilet leads to a contact risk (Jeppesen, 1994; Lechte et al., 1995).

There are many systems for reusing greywater at the household level. In California, systems which use greywater treated to a primary level for subsurface irrigation of gardens, have been in use for many years and studies have shown no health problems associated with their use.

In some cases garden irrigation schemes may not be suitable. There are concerns that chemicals in greywater may damage clay soils, and nutrient-rich greywater may not suit all plants, particularly natives that often require nutrient depleted conditions for growth (Jeppesen and Solley, 1994; Beavers, 1995).

In non-sewered areas of Australia there is a trend towards small scale, single household sewage treatment plants. While the emphasis has been on the disposal of sewage the output from these plants, when properly operated, is generally suitable for subsurface irrigation. These systems require care and maintenance and there is concern that poor quality water might be discharged due to failure to properly maintain them.

In Japan, the most common in-house greywater re-use system is the hand basin toilet. A hand basin is set into the top of the cistern, so water from hand washing forms part of the refill volume. Hand basin toilets are reportedly installed in most new houses in Japan. Japan also has many instances of greywater re-use in high rise buildings. Kiya and Aya (1991) identify 844 buildings in Japan containing wastewater recycling
In view of the above discussion, it can be concluded that:

- Greywater should never be re-used where direct ingestion is possible.
- Untreated greywater re-use should be discouraged due to high bacterial, BOD and suspended solids (SS) content.
- Greywater should only be used for subsurface irrigation of non-edible plants following filtering to prevent blockages and soil clogging.
- Undisininfected treated greywater can be used for sub-surface irrigation provided there is no contact with humans except during system maintenance.
- Where human contact is inevitable, only disinfected treated greywater should be re-used (for example, surface irrigation, toilet flushing, car washing, laundering).

Greywater used for garden irrigation may contaminate groundwater. Excess irrigation may also lead to greywater runoff. The storage of greywater for more than 24 hours can result in offensive odours (Water Authority of Western Australia, 1994e).

In the Western Australian Wastewater 2040 studies, domestic greywater re-use was seen as an acceptable option, again with cost as a possible barrier, particularly if applied to existing housing. Some concerns were raised about possible human contact with greywater in dual reticulation systems.

It seems possible that the public may be more willing to accept greywater re-use than many health authorities or water utilities. Many residential households re-use greywater, particularly from washing machines, for garden watering despite the disease risk involved.

Social surveys conducted in Melbourne indicate that people support the recycling of bathroom and laundry wastewater, although the preferred pay-back period for the installation of a domestic recycling unit is limited at two to four years (Christova-Boal et al., 1994).

### 8.3.2 Dual Reticulation Systems

Dual reticulation systems supply treated wastewater for use in non-contact uses, primarily toilet flushing, and for irrigation purposes (Beavers, 1995).

There are many such schemes in operation in the USA. A review undertaken as part of this study is given in Thomas (1995a). The City of Altamonte Springs, near Orlando in Florida, may be considered typical. The scheme is for non-potable residential uses, and has an output of 10 Mg/d (45 ML/d) of reclaimed water. Its key features are as follows:

- The scheme serves a population of 45 000 people, and the reclaimed water is used for residential garden irrigation, industrial, commercial and public buildings irrigation (including the grounds of the regional hospital), as well as open space irrigation. Some of the reclaimed water is being supplied to office and
apartment buildings for toilet flushing and once-through cooling purposes. The water is also used for lake level control, automobile washing, fountains and waterfalls. Around 30% of the total supply is provided from the reclaimed water scheme.

- The decision to build the re-use scheme came from concerns about the effect of effluent from the previous treatment plant on quality in the receiving water, a wetland, and the need to limit withdrawals of potable water from the Central Florida aquifer.
- Influent comes from a separate sewer system dominated by residential discharges. It is low in salinity.
- The treatment train is (i) primary sedimentation tanks (ii) biological secondary phase which includes anoxic tanks, nitrification tanks, recycle pumps and secondary clarifiers (iii) tertiary phase which includes chemical addition (methanol and alum), coagulation, filtration, re-aeration and high-level disinfection (iv) polishing for de-chlorination and pH control and (v) sludges from the primary and secondary processes being thickened, aerobically digested and de-watered on belt filter presses, for disposal by contract hauling.
- There is comprehensive and continuous process control and a well-equipped analytical chemistry laboratory, which provides frequent quality control reports to the regulator, plus reports of any exceptional events and actions taken as a result of these.
- The scheme provided reclaimed water at an incremental cost of around $0.4/kL (in A$ 1995). Incremental cost covers the treatment plant upgrade and reticulation network for delivery of reclaimed water, but not the sunk cost of the pre-existing sewer network. Trenchless technology was used to retrofit the city with small-diameter pipes for delivery of the reclaimed water. This meant that there was no need to dig up streets, driveways or access paths. The city sits on a sandy soil.
- In introducing the scheme, there seems to have been a mixture of forceful advocacy on the part of the water utility, combined with extensive public consultation, resulting in general acceptance. The city ordinances were amended to enforce compulsory connection to the reclaimed water distribution network.
- No public health impacts were detected in the six years of operation from 1989 to 1995.

Only small scale pilot level non-potable re-use schemes have been operating within Australia. These have involved strict environmental and health monitoring; the retrofitting of households at no cost to the household; and investigation of consumer acceptability. Commercial scale domestic re-use schemes have not yet been developed. However, a large scheme is being planned for Rouse Hill, New South Wales, and a small experimental project has been built at New Haven in South Australia. Planning strategies for the township of Cockatoo, which is not connected to the Melbourne Water sewerage network and the Caroline Springs (Melton East) estate, in Victoria, have investigated the potential for domestic re-use and dual reticulation schemes for households. Domestic re-use and non-potable reclamation has also been investigated as an option in the Plenty Valley area in Victoria (Melbourne Water, 1992b).
Environmental monitoring should be an integral part of any development of domestic re-use schemes. Monitoring of the Shoalhaven Heads (New South Wales) pilot project resulted in the following recommendations for re-use schemes:

- Monitoring is needed to assess environmental impacts.
- Tests for heavy metals, toxins etc should be carried out every six months, depending on site characteristics.
- Soil and groundwater should be monitored every six months to assess changes due to reusing effluent.
- Biophysical characteristics and suitability should be taken into account when selecting a potential re-use site.
- Vegetation should be inspected regularly, as well as recording drainage flows, water-logging, obvious diseases, deaths, abnormal growths and proliferation of weed species.
- Odour problems should be attended to quickly.
- Nearby waterways should be monitored, to determine any water quality changes.

Guidelines developed in 1992, and introduced into NSW for the “Urban and Residential Use of Reclaimed Water” (New South Wales Recycled Water Coordination Committee, 1993), specify the required water quality and the technology needed for a variety of non-potable uses. The strict microbiological standards of the water used in dual water systems are similar to those that would be required for the potable re-use of wastewater. Further similarities are noted, with the basics of a potable reclamation plant already provided within a dual water supply treatment plant.

Non-potable re-use leads to both a reduction in water consumption from other sources and a reduction in wastewater flow rate. So re-use schemes may thus avoid the adverse environmental consequences associated with conventional water sources and wastewater disposal systems.

8.4 Potable Re-use

8.4.1 Direct Potable Re-use

Direct potable re-use involves adding treated wastewater directly into the normal drinking water supply system. Direct potable re-use has been technologically feasible for many years. A potable re-use plant has operated successfully in Windhoek, Namibia, for example, since 1969 (although not continuously). This was followed by a larger demonstration plant at the Daspoort Sewerage Treatment Works in Pretoria. However water from the Daspoort plant has not been used to supplement drinking supplies. In the United States, the Denver Potable Re-use Demonstration Project operating since 1984, has recently ceased operation.

While treating effluent to potable standards is technically possible it has generally been too expensive to be taken seriously as a supply option. However, in evaluating the re-use scheme at Rouse Hill in New South Wales, the cost of a dual non-potable water supply was estimated at $32.5 million. The cost of reclamation to potable standards was higher at $34.7 million. The difference is small enough for potable re-
use to be competitive with the alternative. It is expected that operating costs would be similarly competitive. A potable re-use system also has the advantage that a separate reticulation system is not required, a definite advantage in established residential areas.

Direct potable re-use reduces the volume of wastewater discharged to the environment and reduces the demand on water supply sources. Because potable re-use replaces an alternative supply source, it avoids any environmental penalties associated with the use of that alternative source.

### 8.4.2 Indirect Potable Re-use

Indirect potable re-use consists of discharging wastewater to receiving waters that feed a downstream source for a potable water supply system. Undesirable qualities of the wastewater may be diluted to acceptable levels. A pilot scheme based on this principle was constructed at the Cerro del la Estrella sewage treatment plant in Mexico city, where treated wastewater, which meets the criteria for potable re-use (except for total dissolved solids (TDS)), is diluted by water from other sources.

A typical form of indirect re-use occurs where wastewater is disposed to a river that forms all or part of a downstream township’s drinking water supply. One example is the Thames catchment. It is often said that a water consumer in east London may drink water that has been recycled through seven or more sewage treatment plants. Inter-town distances along U.K. rivers are short. Thus a large proportion of water supplies in the U.K. are from indirect potable re-use. Similar situations prevail in many countries, including Australia.

### 8.5 Industrial/Commercial Re-use

The most common industry use of reclaimed water is non-contact cooling. Examples include the Curtis Stanton Energy Centre and McKay Bay Refuse-to-Energy Facility, both in Florida. Reclaimed water may also be re-used as industrial process water or boiler feed water. For example, the Xerox Corporation in the USA uses approximately 4ML/day of reclaimed water in paper manufacturing.

Quality requirements for industrial water vary with the use. Boiler feed water must typically be of very high quality, to avoid corrosion and scale problems. Cooling water generally has lower quality requirements, however even in this application, reclaimed water may be less desirable because evaporation in cooling towers concentrates impurities in the water. Cooling water must be discharged as waste (blowdown) once a certain concentration is reached. The impurities in wastewater implies that it must be discharged more frequently, resulting in increased total water use and volume of water discharged from the industrial site.

Health issues associated with the industrial re-use of wastewater include the microbial contamination of wastewater; growths in the cooling tower; and pathogens released in the blowdown of concentrated wastes after evaporative cooling. However, the effect
of micro-organisms under these circumstances would be well below typical occupational exposure limits (Hartley et al., 1991).

In view of the positive attitude that the public holds towards wastewater re-use, there can be little doubt about the acceptability of industrial re-use. However there are potential problems if the wastewater increases odour or has perceived health problems.

The benefits of industrial re-use include a reduction in the volume of waste discharged to the sewerage system and the avoidance of environmental effects associated with equivalent augmentation of scheme water headworks. The disadvantages include the increased discharge to the environment of cooling tower chemicals, and the environmental effects associated with the cooling water treatment plant (Hartley et al., 1991).

8.6 Re-use In Groundwater Systems

Treated sewage or stormwater may be deliberately recharged to aquifers in order to achieve one or more of the following aims:

- It may provide a means of storage during periods of low water demand.
- The aquifer may be used as a method of water distribution and additionally provide a stage of water treatment.
- Wastewater of particular qualities may be used to improve the overall water quality of the aquifer. For example wastewater with low salinity may be added to a brackish aquifer to make the water drinkable.

Wastewater may also be used to deliberately recharge groundwater systems for other purposes, for example, to prevent saltwater intrusions into an aquifer. The Water 21 Factory in Orange County, California, accepts sewage from a large part of southern Los Angeles. Following tertiary treatment, the effluent is used for injection to groundwater in order to create a mound which will prevent ingress of salt water across the coastal aquifer which itself has been depleted by past withdrawals. It is also planned to pump the treated effluent inland and inject it within a recharge area for an aquifer which is used for potable supply purposes.

Dillon et al., (1994) undertook an extensive review of the international literature regarding injecting water for storage and re-use. Pilot trials using treated sewage effluent are now in progress in Basos-Riera D’Horta (Spain), and Bay Park, Cedar Creek, and El Paso (in the USA).

To date in Australia, artificial aquifer recharge using sewage effluent has only been piloted in Carrum, Victoria in the 1970s (Lakey, 1978). However pilot studies are underway to investigate the use of stormwater runoff for aquifer storage and recovery at Andrews Farm, South Australia. Waters from the Bremer Creek and Brownhill Creeks respectively are being used to control a saltwater intrusion and enhance irrigation supply elsewhere in Australia.

Water quality criteria for recharge relate to the beneficial uses of the reclaimed water. Throughout the USA, effluent must be tertiary treated if used for aquifer recharge in order to comply with the US EPA Drinking Water Standards. Recharged water has
been used for drinking, irrigation and industry. Hydrogeological factors are important, and aquifers with high transmissivity are preferred. Most aquifer types used for recharge are sedimentary formations. Clogging can result from physical, chemical and biological processes (Dillon et al., 1994).

With the exception of increases in viruses, bacteria and ozonation products groundwater quality usually improves following injection. Lake water (not treated effluent) in Israel that was used for recharge resulted in bacterial growth around the well, limiting a potential use for the water as a potable supply. Further studies are required related to attenuation processes within aquifers to treat the injected water to an acceptable standard for pre-defined beneficial uses (Dillon et al., 1994).

A study has been undertaken to determine Australian guidelines for the quality of water injected into aquifers (Dillon and Pavelic, 1995). The major issues addressed in this study include water quality requirements for groundwater protection; operational problems such as clogging and how to resolve these issues. International experience suggests that with appropriate management, water quality and technical problems may be overcome.

### 8.7 Stormwater Re-use

The runoff from Australian cities equals or exceeds the amount of potable water supplied to homes each year (Dowsett et al., 1995). About 50% of water supplied is used for purposes where less highly treated water would suffice (such as for watering gardens, toilet flushing). Stormwater re-use would be an effective alternative water source in cities such as Adelaide and Perth, for example, where rainfall typically occurs during the winter months with very little occurring during summer. An effective means of storing winter stormwater locally could provide a useful alternative supply for summer (Engineering and Water Supply Department, 1993).

A range of potential stormwater reuse techniques are available. In New South Wales, for example, Dowsett et al., (1995) recommend that state and local government should provide financial incentives for the implementation of on-site detention, reuse and/or underground retention of stormwater. On-site detention, when used on unpaved or grassed surfaces, may be used to trap and remove contaminants from stormwater and increase infiltration into the ground (CEPA, 1993). Constructed (or artificial) wetlands may be used to collect rainfall runoff and help transform stormwater from a problem into a viable resource (Dowsett et al., 1995). According to Clark (1992), it is estimated that artificial recharge using urban stormwater has the potential to provide a source of water for irrigating an Adelaide college ground at less than half the current cost of mains water. Dowsett et al., (1995) recommend that the potential for recharge of the Botany aquifer with treated stormwater as a means of augmenting Sydney’s water supply for non-potable purposes should be investigated. A more detailed discussion of stormwater management is presented in Part III.
8.8 Sludge Re-use

Sludge re-use is beyond the scope of this paper, but it should be noted that an increase in the level of treatment of sewage, which would be implied by many of the re-use schemes considered here, would lead to an increase in the amount of sludge to be disposed of. There is already an upward trend in sludge production, which is largely due to improved sewage treatment practices and increased sewage flow (Gibbs et al., 1993). If re-use is to increase substantially then it must be possible to safely and economically dispose of the sludge produced.

Disposal methods once used for sludge management, such as ocean disposal, are now considered environmentally inappropriate. Two trends in sludge management have developed overseas. In Europe, there is a push towards dual management of sludge, both for environmentally correct incineration and landfills. America is pursuing land application/re-use options. Australia is also considering this as a possible alternative to existing sludge management techniques (Waste Management and Environment, 1994b).

New South Wales leads Australia in the adoption of sludge re-use options. In 1989, over 60% of the sludge handled by the Water Board was disposed of primarily into the ocean. By 1993, nearly 70% of the sludge generated was being re-used and disposal to the ocean had ceased. The Bolivar Sewage Treatment Plant in South Australia and some regional centres have also developed sludge handling facilities.

The development of appropriate regulatory guidelines and health issues are major issues relating to sludge re-use. As with most effluent and wastes, the regulations governing sludge disposal and re-use are implemented within states, involving government departments of health, agriculture, environment and waste management (Gobbie, 1991). The NSW Environmental Protection Authority’s “Environmental Guidelines for the Use and Disposal of Biosolids” is the first of its kind in Australia and provides a framework for the sustainable use and disposal of biosolids. Studies are also being undertaken by NSW Agriculture and NSW State Forests. National guidelines for sludge management are being developed by a working party of ARMCANZ (Waste Management and Environment, 1994b).

There are some health concerns linked to the re-use of wastewater sludge. Sludge generated at metropolitan plants contain heavy metals, pesticides and other contaminants (Kayaalp, 1994). While often in low concentrations within the sludge, contaminants may build up in fatty tissue when ingested via the food chain (Gobbie, 1991). Concerns also arise when people come in direct contact with the waste (Kayaalp, 1994). These contaminants are thought to enter the sewerage system through illegal discharges and from industrial sources. Therefore action to reduce the level of contaminants in sludge can focus on physically removing them, or controlling them through a more cost-effective, strict trade waste policy (Gobbie, 1991).

Queensland sludge management will be based on guidelines developed by the Department of Primary Industry. Biosolid supply will be divided into three classes based on their heavy metal and organochlorine compound concentrations. Class A biosolids will be suitable for unrestricted public sale; class B will have a slightly
higher level of contamination, for land application and site management practices; class C biosolids will have still higher contamination concentrations (still within guidelines) and remain under the control of the local council (Waste Management and Environment, 1994b).

8.9 Conclusions

The study has concluded that a variety of potential markets exists for reclaimed water:

- It appears highly likely that some urban water demands could be effectively supplied by reclaimed water, either to potable or non-potable standard.
- As the cost of treating water to potable standards decline, this option may become more attractive over time especially if wastewater treatment standards increase.
- Assessment of the retrofit market can only be done on a plant-by-plant basis taking account of urban layout, topography, soils, demand and costs. Retrofitting dual reticulation is probably not an economically viable option for many existing housing or infill developments, though advances in trenchless technology are cutting the costs of retrofitting. A potential market exists in new developments where dual reticulation can be incorporated into the initial design and costing.
- The potential market for greywater for domestic non-contact uses is large. Without adequate levels of treatment, however, the greywater is probably only acceptable for sub-surface garden irrigation. In this case, capital costs of setting up these schemes may be the major limitation.
- The market for urban irrigation will depend on the amount of public open space and the level of irrigation required. Although small in overall terms, the urban irrigation market can be significant in reducing discharges to sensitive environments.
- Industrial use of reclaimed water is an important market. Industry and commerce use approximately a third of urban water in Australia and the demand pattern is relatively constant throughout the year. Due to the variations in water quality requirements of different markets, adequate treatment levels must be ensured to avoid problems such as corrosion, staining, scale deposition and foaming.
- Irrigated agriculture and woodlots on the fringes of urban areas is an important market.
- In country towns there is considerable scope for both re-use in irrigation and for land disposal.

9. PUBLIC ACCEPTABILITY AND HEALTH ISSUES

9.1 Public Acceptability of Re-use

Several Australian water agencies have studied the acceptability of wastewater re-use, including Brisbane City Council, Melbourne Water, Sydney Water, ACT Electricity and Water, SA Water and the Water Authority of WA. In these studies, often involving workshops, the community has been found to be generally in favour of re-use. In fact there has been strong resistance to current disposal methods, which have been seen as both environmentally damaging and the waste of a potentially valuable resource.

In 1988, the Brisbane City Council carried out a survey of 1508 community members, in which potable re-use of wastewater was one of the issues raised (Hamilton and Greenfield, 1991). The results stated that 13.3% of respondents agreed that wastewater should be recycled for drinking. Of the remainder, 57.4% disagreed but did not strongly disagree, indicating that respondents were not as critical as they might have been (Hamilton and Greenfield, 1991). Results of a survey conducted by the University of Queensland in 1991 concluded that:
those who are already convinced of the value of potable re-use account for approximately 20 per cent of the population while those that would never accept the idea no matter how good it was account for less than 5 per cent. (Hamilton and Greenfield, 1991, p. 505)

The vast majority of the population therefore needs to be convinced of the viability and reliability of the potable re-use option. This could be achieved through community education and pilot demonstrations (Hamilton and Greenfield, 1991).

A review of community opinions in Victoria showed a clear distrust of the potable re-use option (Melbourne Water, 1992a).

Potable re-use was raised as an option at the Perth Wastewater 2040 Community workshops. Participants felt that, while it was a technically acceptable option, its cost was excessive. Health issues were not perceived to be a problem by this group.

At the same time, health concerns are frequently raised by the public, particularly in relation to residential re-use schemes and the irrigation of urban recreational areas and crops for human consumption.

9.2 Known Public Health Impacts of Re-use Projects

There are many texts which vividly describe the potential health effects of drinking contaminated water. These include typhoid, cholera, hepatitis A and E, euteric fever, gastroenteritis, giardiasis, amoebiosis, and cryptosporidiosis. Skin diseases may also arise from contact with contaminated water or from aerosols. Forsyth (1993) provides a summary of Australian experience.

However, the literature only serves to emphasise that all stages of water supply and wastewater treatment must be carefully controlled and monitored. Reclaimed water systems are just one technical variant.

As the longest period of experience with large-scale re-use projects is in the USA, particular attention was paid to the availability of documented public health investigations in that country. The most general statement of the public health effects of re-use schemes in the USA is given in the US EPA Guidelines for Water Re-use, (p. 25):

_Epidemiological investigations directed at wastewater-contaminated drinking water supplies, use of raw or minimally-treated wastewater for food crop irrigation, health effects to farm workers who routinely contact poorly treated wastewater used for irrigation, and the health effects of aerosols or wind-blown spray emanating from irrigation sites using undisinfected wastewater, have all provided evidence of infectious disease transmission from such practices._

_However, epidemiological studies of the exposed population at water re-use sites receiving disinfected reclaimed water treated to relatively high levels are of limited value, because of the mobility of the population, the small size of study population, the difficulty of determining the actual level of exposure of_
each individual, the low illness rate – if any – resulting from the re-use practice, insufficient sensitivity of current epidemiological techniques to detect low-level disease transmission, and other confounding factors. It is particularly difficult to detect low-level transmission of viral disease, because many enteric viruses cause such a broad spectrum of disease syndromes that scattered cases of acute illness would probably be too varied in symptomology to be attributed to a single etiological agent.

The limitations of epidemiological investigations notwithstanding, water re-use in the U.S. has not been implicated as the cause of any infectious disease outbreaks.

Kindzierski and Gabos (1994) reviewed health effects associated with wastewater treatment, disposal and re-use. While they point to well-known health problems with overflows of untreated sewage, particularly Hepatitis A illness, and problems with raw wastewater irrigation, they reported no public health impacts form the use or reclaimed (that is treated) wastewater. They did, however highlight the importance of application technologies for edible crop irrigation using reclaimed water, and the importance of monitoring of groundwater recharge schemes using reclaimed water.

At a more specific level, the City of St Petersburg, Florida, Public Utilities Department commissioned a panel of experts covering environmental engineering, viral epidemiology, and environmental microbiology to undertake an assessment of health risks from the city’s re-use scheme, which is one of the largest and longest running in the world. In conducting their investigation the consultants emphasised that treatment schemes must always be designed to eliminate, or at least minimise, the potential risk of disease transmission.

To estimate the potential risk it is necessary to examine clinical and epidemiological information related to the infectious agents of concern. It is not necessary to repeat these factors here. They are well documented in the US EPA Guidelines (Camp, Dresser and McKee, 1992) and the Australian Draft Guidelines for Wastewater Re-use, (1995) (National Water Quality Management Strategy, 1996a). The consultants to the City of St Petersburg found:

- no evidence of increased enteric diseases in urban areas irrigated with treated reclaimed wastewater using coagulation, filtration and disinfection, and
- no evidence of significant risks of viral or microbial diseases as a result of exposure to effluent aerosols from spray irrigation with reclaimed water (Camp Dresser and McKee Inc, 1987).

The consultants provided recommendations about design, construction, operation, monitoring and turbidity/faecal coliform standards. They recommended against the introduction of virus standards, because of the adequacy, as they perceived it, of surrogate measures. However, they did recommend that the distribution system should be checked for bacterial growth, as well as the treatment plant. These aspects have been considered in the Australian Draft Guidelines for Wastewater Re-use, (1995) (National Water Quality Management Strategy, 1996a).
Because of the limited extent of urban re-use schemes in Australia, there is little accumulated evidence of their public health impacts. However, one case of infectious disease outbreak was reported in the Australian Medical Journal (Flood et al., 1994). The article reported that, while not proven, there was strong circumstantial evidence that an outbreak of *Mycobacterium ulcerans* in a community on Phillip Island, Victoria was associated with spray irrigation of a golf course (using treated reclaimed wastewater). Both golfers and nearby residents were affected. (*Mycobacterium ulcerans* produces deep skin lesions that must be surgically removed. The disease is commonly known as Barnsdale Disease, and the bacterium is endemic in the soils of the Mitchell River floodplain in Queensland.) The outbreak ceased after modification of the storage and irrigation regime. The Infectious Diseases Unit at Fairfield Hospital in Melbourne is examining the case and is trying to develop methods to detect the bacterium in the environment. It should be noted that the Victorian Department of Health and Community Services believes that the environment of north east Phillip Island probably became contaminated with bacteria sometime in the early 1990s, but that it is unlikely that the treated wastewater was the source of the bacteria. However, it has not ruled out the possibility that increased soil wetness caused by the golf course irrigation system may have increased the risk of infection. It is thought that the treated wastewater may have been contaminated by contact with infected soil or groundwater in the golf course dam and became an infection pathway. Further to this, the majority of cases occurred during winter, when there was little use of treated wastewaters.

Recently, the performance of the Rouse Hill, NSW coagulation/floculation treatment process with respect to the control of *Cryptosporidium* and other pathogens has been reviewed. The report indicated a preference for microfiltration or reverse osmosis for disinfection purposes. Such quality control issues are encountered in most water supply schemes: for example a treatment plant was installed for Sydney water supplies because of emerging problems with *Giardia* and *Cryptosporidium* in surface water catchments.

### 9.3 Role of Re-use Guidelines and of the Regulator

In most States and Territories throughout Australia, the approval of both the Health Department and the Department of Environmental Protection would be needed for re-use schemes to proceed.

In the USA, State Governments provide detailed re-use regulations which require the active oversighting of the quality control aspects of treatment plant operation by a regulatory agency external to the water utility. This comprised weekly laboratory reports and a system of exception reporting which obligates the utility to report any situation where the treatment plant goes out of normal bounds, the reasons for this, and the remedial actions taken. This arrangement was particularly valuable to the re-use industry, as it provided both visible public endorsement of the treatment plant operations, and consumer protection.

In discussions with Australian water managers who are investigating further re-use projects, there was some dissatisfaction with the National Water Quality Management Strategy (1996a) on Use of Reclaimed Water. It was felt that insufficient
differentiation of the target quality for reclaimed water had been made with respect to
the particular irrigation system being used. For example, imposing a water quality
standard suitable for spray irrigation on a well-controlled micro-irrigation scheme
might be considered to be over-cautious.  (*This observation was noted by the authors
of the Draft Guidelines, which were subsequently modified: editor*).

9.4 Conclusions on Public Health and Acceptability

The Phillip Island case described above is consistent with the statements of the US
EPA and of the City of St Petersburg public health consultants. It serves to emphasise
the importance of correct design, construction, operation and maintenance of re-use
projects. Re-use in Australia may encounter problems specific to our environment; for
example through the prevalence and ambient conditions for particular bacterial and
viral species. It is desirable that research be encouraged on Australian pathogenic,
viral and bacterial species in wastewater, and the ambient conditions for their propa-
gation and transmittal. Adequate risk assessment methodologies are needed for
Australian re-use projects.

Strong public education and public involvement programs are essential to the planning
and operation of re-use schemes. These activities should include schools programs,
Visitor programs to treatment facilities, general public information provisions and
community involvement in decision-making about new re-use schemes.

The dominant impression gained from USA practices, is that the encouragement of
wastewater re-use is now an established policy and accepted at national level. It seems
likely that there will be a tripling in the volume of reclaimed water re-used in the USA
by the year 2000. Wastewater reclamation and re-use has been an established practice
in several states, notably Florida and California, for over 20 years. Florida and
California together reclaimed more wastewater in 1994 than the total wastewater flow
in New South Wales. There is no evidence that infectious disease outbreaks in the
USA have been associated with the use of reclaimed water that has been treated to
relatively high levels. Wastewater re-use has become an accepted part of the water
supply system in California and Florida. However this was not achieved without
effort. All re-use programs were accompanied by public involvement campaigns.
Public involvement took the form of school programs, visitor programs to reclamation
facilities and active communications activities. The importance of strong public
education programs and public involvement in decisions about the development of re-
use projects was emphasised.

In Australia, several water authorities have studied the public acceptability of waste-
water re-use. The community was generally found to be in favour of re-use. In fact,
there was considerable community resistance to disposal schemes, which were seen as
wasting a potentially valuable resource and having potential environmental problems.
Marine disposal, particularly was not favoured by the community, being seen as not
only wasteful but potentially polluting.

Health concerns are frequently raised by the public, particularly in relation to
residential re-use schemes, but also about irrigation of urban parkland and crops for
human consumption. However this should not detract from the generally favourable response to these schemes.

Recommendations on the appropriate methods and degree of treatment required for specific water re-use projects must be assessed not only from a technical and economic perspective, but should also take into account community concerns, and address the National Guidelines for Wastewater Re-use.

10. ECONOMICS OF WASTEWATER RE-USE

10.1 Engineering Costs

The engineering assessment of re-use or land application projects requires an evaluation of average and peak demand characteristics, level of service in terms of reliability and water quality, treatment plant influent quantity and quality, required treatment train, hydraulic flows, pipe and pump station requirements and service reservoir storages, distances to re-use/land application site, and conditions at the re-use/land application site. These factors will obviously vary between locations.

The literature survey did not yield any recent published engineering cost evaluations of re-use projects, though the United States Environmental Protection Agency (1978a, b, and c) has published indicative data. Pound et al., (1975) provided cost comparisons for land application versus advanced wastewater treatment. While their original data, in US dollars, are now of little interest in Australia, some of their conclusions are still relevant:

- In general, land application systems exhibit less economies of scale than advanced treatment and thus tend to be more cost effective at lower flow capacities.
- If conditions (including sale value of the crop) favour irrigation, then re-use schemes exhibit greater economies of scale.
- Land application systems remain cost-effective at higher flow capacities if the only alternatives are higher-level advanced treatments such as biological nutrient removal, lime addition, or ion exchange.
- Infiltration/percolation are the lowest cost land application system under suitable conditions.
- Land price is critical in determining the viability of land disposal. In general, the lower the flow capacity of the land application system, the higher the price that can be paid for the land while remaining cost-competitive with advanced treatment.
- If transport distances are small, then irrigation and overland flow systems are cost-competitive with moderately advanced treatment.

Assessing economic viability is more complicated in urban retrofit situations. The conceptualisation of re-use schemes is of necessity opportunistic, involving the matching of design and construction options to available demands in a cost-effective manner. The rapidly increasing use of trenchless technologies for pipe installation in a variety of terrains is changing the relative cost of retrofits. For example, the availability of trenchless technology was a key factor in the cost-effectiveness of the retro-
fitted reticulation system for supply of reclaimed water to the 45 000 population of the City of Altamonte Springs, in Florida in the late 1980s. The improving performance of package treatment plants for use in sewer interception schemes creates opportunities for grafting re-use facilities onto existing dendritic sewage collection systems, thus avoiding the need for expensive pump-back from a large plant situated at the bottom of the collection system.

As the number of technical options increases, there is increasingly a need to evaluate decentralised systems against the more traditional centralised systems. Clark (1995) has shown that the scale economies of large treatment plants in centralised systems is virtually offset by the scale diseconomy of the trunk mains needed to transport sewage to the central treatment plant. As a result, average costs of the sewage handling system are relatively invariate over different scales of collection system.

The engineering assessment of re-use projects requires careful evaluation of average and peak demand characteristics, level of service required in terms of reliability and water quality, treatment plant influent quantity and quality, required treatment train, hydraulic flows, pipe and pump station requirements and service reservoir storages. These factors will obviously vary between locations.

As the number of technical options increases there is increasing need to evaluate decentralised systems against the more traditional centralised systems.

Although limited in extent, several wastewater re-use facilities have been trialed in Australia. The Southwell Park wastewater recycling plant in Canberra, and the Rouse Hill Development Project in Sydney demonstrate costs of introducing water re-use and recycling in established and new urban developments, respectively. The Power and Water Authority in Darwin is evaluating a re-use plan which provides a simple example of infrastructure cost saving from re-use.

Southwell Park, Canberra: The Southwell Park water mining plant (believed to be the first of its kind in the world) is a custom-designed and manufactured three-stage sewage treatment facility located in the suburb of Lyneham, North Canberra. Recycled water from the plant is used to irrigate the surrounding playing field and park area of nine hectares, with future plans to include the irrigation of the nearby Yowani Golf Course, Canberra Racecourse and Canberra Showgrounds. The facility is capable of producing an initial output of 300 kL of treated water per day. The plant was jointly funded by ACT Electricity and Water (ACTEW) and the Commonwealth Government Better Cities Program, at a cost of approximately $2.4 million, including $850 000 for civil construction.

Amortising the capital costs (over a 20 year period, using a discount rate of 8%), annualised capital costs are $240 000. The plant is in its first year of operation, so no firm operating and maintenance (O&M) costs estimates are available. Since no labour is required to maintain the plant on a regular basis, O&M cost are estimated to be approximately $60 000 p.a. Total annual costs are therefore, estimated to be $300 000. Based on an output of 300 m$^3$/day, the costs of supplying reclaimed water are estimated to be $2.74/m$^3$. It is considered that throughput could be approximately doubled with little additional cost, virtually halving the unit cost. Also, as a prototype, the capital costs were higher than would be achieved in a larger production run of
similar plants. As primary water supplies become limited, as economies of scale are realised (in either up-sizing the plant or by having multiple plants), and as the discharge of treated wastewater to receiving waters becomes less socially acceptable (from an environmental perspective), treatment plants such as this may become economically efficient.

*Rouse Hill, Sydney:* The Rouse Hill urban development project is by far the largest re-use scheme so far considered in Australia. In an attempt to integrate urban planning with environmental management, an integrated water cycle management system has been developed, which features water recycling, a drainage system that makes full use of existing landforms, and a state-of-the-art wastewater treatment train, incorporating a constructed wetland (Environment, 1994).

The following equation may be used to calculate the unit cost of the Rouse Hill scheme:

\[ U = C + P \]

where:

- \( U \) = unit cost (in $/m^3)
- \( C \) = operating and administrative cost ($/m^3)
- \( P \) = the constant annual charge (per m^3) for reclaimed water required to recover capital costs over the life of the project (assumed 30 years)

\( P \) was calculated from:

\[ K = \sum_{T=1}^{30} \frac{P \times QT}{(1 + R)^T} \]

\( i.e. \quad P = K \left( \sum_{T=1}^{30} \frac{QT}{(1 + R)^T} \right) \)

where:

- \( K \) = discounted capital costs ($)
- \( R \) = discount rate expressed as a proportion
- \( T \) = number of years elapsed since project started
- \( Q \) = annual demand for reclaimed water as a function of \( T \), time.

Assuming discounted capital costs (\( K \)) of $32.5 million; a discount rate (\( r \)) of 0.05, \( T \) from 1 to 30 years, and a \( Q \) value of 0.73m\(^3\) x 10\(^6\) (based on the data in project design reports), a constant annual charge of $ 0.24/m\(^3\) of reclaimed water delivered to consumers would recover capital outlays of the re-use scheme. It is evident that, even with the addition of operating and administrative overheads, this scheme appears cost-competitive. The calculation takes no account of distribution system losses, but nor does it consider cost savings in other parts of the sewage system, in particular any cost savings for higher treatment prior to discharge, if re-use is not undertaken. However, according to the above calculations capital recovery rates, shown below, would be fairly slow:
Table 7. Estimated capital recovery rates under the Rouse Hill Re-use Scheme

<table>
<thead>
<tr>
<th>Elapsed Years</th>
<th>% Capital Outlay Recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>21</td>
</tr>
<tr>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>30</td>
<td>100</td>
</tr>
</tbody>
</table>

Darwin Re-use Project: In Darwin the re-use of effluent could potentially take up to 20% of the wastewater flow, or approximately 1 million m$^3$/yr. This could delay the construction of a new dam by two to three years, thus delaying capital expenditure of around $200 million. The cost of treated effluent is thought to be approximately $1.50 per m$^3$/yr. The benefits (cost savings) of a delayed dam construction may be estimated at approximately $30 million (that is the changed net present value of the $200 million expenditure), which expressed as an annual value equates with a benefit of $3.0 per m$^3$ of the reclaimed wastewater flow.

10.2 Environmental Economic Analysis of Wastewater Re-use Projects

The engineering cost estimates of the kind discussed in the proceeding section may need to be supplemented by a full cost-benefit analysis (CBA) if a correct decision about whether to proceed with re-use is to be reached. The aim of this section is to provide an overview of the use of CBA to assess the economic feasibility of alternative wastewater re-use programs.

Associated with the problem of water management are potentially conflicting economic and environmental objectives which, on one hand, aim to maximise private economic returns from water use, and on the other from a society viewpoint, aim to conserve the ecological standards of both land and aquatic environments. Environmental economic analysis provides a general framework to help manage resource uses in a way that takes account of society-wide effects. As such, it:

- provides a framework for management of the environment
- indicates the relative net benefits of competing resource uses
- assesses the impacts of different policies and programs on externalities, and
- provides information on gains and losses to different groups in society.

(Commonwealth of Australia, 1995)

Decisions concerning the environment always involve benefits and costs, some with monetary value and some without. Environmental CBA provides an effective method for judging the economic efficiency of proposed wastewater re-use strategies. CBA of recycling and reusing water is discussed extensively by Spulber and Sabbaghi (1994).

In order to assess the costs and benefits of planning and investment in water re-use, the analysis of policy should include:

- holistic supply side analysis
- an extensive analysis of water demand of individual user segments (households, industry, public utilities, agriculture), and
- externalities, especially changes in the state of the environment.
Water re-use projects both complement and compete with programs of conventional water-supply protection, water resource development and water quality improvement (pollution abatement programs) because re-use entails potential reductions in fresh-water withdrawals or groundwater depletion as well as improved surface and groundwater quality.

10.2.1 Supply-Side Analysis

Water recycling and re-use can be viewed as a viable option within a broader framework of supply augmentation. In the case of both primary and re-use water supplies, the optimum level of water use will occur where the marginal system-wide cost of extracting and treating a unit of water is just equal to the benefits obtained from the use of that unit of water. This represents the level at which marginal net benefits (benefits minus costs) are at a maximum. Primary and re-use water, however, do not have identical marginal benefit and marginal cost curves. Consequently, the optimum combination of primary versus re-use water will vary according to local circumstances.

Comparable planning and evaluation techniques can be applied to manage re-use at the regional level and to determine efficient recycling at the plant level. The economic efficiency of re-use will depend on a number of factors, including: the costs of the alternative sources of water, locational advantage, the costs of the treatment level needed to provide effluents of suitable quality, and on potential external dis-economies.

10.2.2 Water Demand

Little is known about how the demand function for water in Australia varies as water supply quality varies. Yet it is clear that quality requirements change radically, depending on the use of water, and that the price that users would be prepared to pay for water supply quality improvements would depend on the use. The value that users place on water of high quality may be estimated by calculating any costs that the users may face if their water supply quality declines (for example: obtaining alternative water sources, decreased production).

10.2.3 Externalities

Water supply developments (including programs of supply, resource development, quality control and re-use) that improve the quality of water bodies, will affect both the instream uses of water bodies (for swimming, fishing and boating) and withdrawal uses (by industry and public utilities). The costs incurred for these programs yield the benefits of increased water quantity and quality for these instream and withdrawal uses. For households, this results in aesthetic and recreational amenities from instream uses, indirect benefits from lower product prices, and direct benefits from better water and sewerage at lower charges. In addition to these household benefits, any reduction in water production costs from increased water quality and availability, and from reduced disposal costs not passed on to households in the form of lower prices must also be counted as an increase in total social benefits.
10.2.4 A simple economic model

Pollution abatement can be achieved through changes in: inputs, production, outputs, various pollution-abatement facilities and technologies, and through regulation. For each individual firm (water utility), the optimal level of pollution control is obtained by equating marginal social benefits of pollution control with the marginal costs associated with abatement expenditure. Again the marginal costs and benefits of the pollution control will differ from case to case as input, outputs, technologies and externalities differ. A simple model of the re-use problem from these perspectives is presented below.

The cost of a town water supply and its associated wastewater scheme is made up of several components:

- the cost of obtaining the water, which includes: the cost of treatment to required levels; the provision of adequate storage; and the costs of any economic, social or environmental impacts that arise from development of the source
- the cost of distributing the water, including: the costs of pipelines, service reservoirs and pumping facilities. In some cases, a major advantage of re-use is that the reclaimed water supply is located near the water use
- the cost of disposing of wastewater after use, including the cost of town sewerage systems. It also includes the environmental abatement costs associated with disposal, such as higher treatment levels or larger ocean outfalls, as well as any environmental damage costs (for example to recreation and tourism, or fishing operators).

A simplified flow network of water and wastewater in an urban area under a conventional system and a simple recycling system is shown in Figure 3 and Figure 4, respectively. From Figure 3(a), an external catchment supplies water to the city through a conventional distribution system. Approximately 50% of the water delivered to consumers is assumed to be used outdoors, and this escapes to the urban environment following use, through evapotranspiration, infiltration to the ground or by surface runoff. The rest is delivered by sewers via a sewage treatment plant to a receiving waterbody, which might be a river, lake, estuary, evaporation pond embayment or coastal water.

There are simplifying assumptions in these diagrams, including the following:

- There is just one source of water supply.
- There is no exchange between the urban environment and the water supply or sewerage pipes, for example, by the use of local stormwaters, sewer overflows, or by exfiltration or infiltration.
- All the water that enters the sewage treatment plant is assumed to be passed to the receiving water body, implying that all sludge is solid.

Nevertheless, Figure 3 summarises the principal features of a conventional city water supply.

Figure 4(a) elaborates Figure 3(a) by introducing a sewage reclamation project. Consumers now receive 30% of their water from the re-use scheme and 70% from the external catchment. Wastewater flow in sewers remains the same as in Figure 3(a), as
does the loss to the urban environment following use by consumers. In practice, a re-use project is likely to be phased in according to the requirement for additional water for a growing city. In this example, total consumption, including the re-use component, has been kept constant, at 100%.

The network segment-specific average costs (capital and operating) for the conventional and recycling systems are shown in Figures 3(b) and 4(b), respectively. It is assumed that the costs of water supply from the external catchment are $1/m³, and the cost of transporting wastewater from consumers to the sewage treatment plant is also $1/m³ of sewage transported. The sewage treatment plant costs $0.5/m³ of throughput, and the system of delivering treated wastewater to the receiving water body through an outfall costs $0.3/m³. The costs of the re-use segments (sewage treatment plant upgrade plus costs of re-distribution) have been set at $1.30/m³. These unit costs, while notional, are not unrealistic for an Australian water utility.

Finally, the bracketed $ figures in Figures 3(c) and 4(c) are the flow-weighted unit costs for each segment for the two systems. By adding these flow-weighted costs across the whole system we obtain an average price per m³ of water delivered to consumers which would recover the costs of the entire water supply and wastewater service.

Leaving aside issues of tariff structure, the mix of access and volumetric charges etc, this average price then represents the total revenue of the water utility, divided by the volume of water delivered to consumers. Thus all costs are recovered through a uniform flat rate charge on water delivered, as in the Hunter Water Board. While this may seem unrealistic for other Australian water utilities, which separate water and wastewater charges on consumers, it is not unrealistic in comparison to the airline industry, for example, which covers all aspects of an integrated service including booking, airports, air traffic control, noise pollution tax and the aeroplane flight in a single charge for the flight ticket.

The surprising result is that the costs of the conventional system in Figure 3(c) and the re-use system in Figure 4(c) are the same: namely $1.90/m³. Why are average costs identical under the two systems, when it is clear that the recycled water is more expensive to treat and transport than raw water in the conventional system? For equal total cost in the two systems, the cost of the reclaimed water in 4(c) must be equal to the opportunity cost of water supply PLUS the cost of discharging to the receiving water body in 3(c). In assessing whether a re-use project is worthwhile, a bald comparison of the cost of a conventional water supply with the incremental cost of a re-use scheme leaves out the benefit in 4(c) of a reduced discharge cost as compared with that in the conventional system in 3(c).

To summarise, it is a common error, when comparing conventional and re-use systems, to look only at wastewater treatment and transportation costs. This fails to take into account changes that are occurring at the source and sink end of the system. At the source, the total cost of transporting primary water to the consumer will be reduced by the amount that has been replaced by recycled water. At the sink end of the system, wastewater that is recycled no longer requires special arrangements for discharge, such as ocean outfalls, and does not need to be released to receiving waters.
Therefore, as long as the costs of treating and transporting wastewater to consumers for re-use are less than the above-mentioned source and sink costs, wastewater recycling may be considered an economically viable option.

A further implication is that for the socially ‘correct’ decision to be made about whether to implement the re-use option, the prices of all inputs faced by the water utility must reflect true opportunity costs, including any externalities associated with the diversion of water or discharge of wastewaters. While re-use schemes are frequently evaluated by considering only the financial cost to the water authority, this may not reflect the full economic impact of the scheme. Thus the cost of a water-supply option must be considered in relation to the alternative schemes available and may include costs and benefits not usually included as direct costs to the water authority.

Water industry regulators and utilities should undertake system-wide environmental benefit-cost analyses to determine whether re-use schemes are efficient. These analyses should identify the opportunity costs of water abstraction and wastewater discharge options, as well as the appropriate infrastructure costs, and lead to appropriate institutional responses.

FIGURE 3a. Water flow volumes under conventional water supply and wastewater system (percent of total supply)

FIGURE 3b. Segment-specific unit costs for a conventional water supply and wastewater system ($/m^3$ of throughput in each segment)
FIGURE 3c. Flow-weighted unit costs for conventional water supply and wastewater system ($/m³ of water supply)

Σ flow-weighted segment costs = av. costs to consumer
= $1.90

FIGURE 4a. Water flow volumes under a simple wastewater recycling system (percent of total supply)

FIGURE 4b. Segment-specific unit costs for a simple wastewater recycling system ($/m³ of throughput in each segment)
10.3 Cost of Nutrient Removal

In an attempt to reduce total loads and concentrations of phosphorus in effluent streams, a range of upgrading treatment processes and a plant rationalisation program have been introduced by the Sydney Water Board (now Sydney Water). The Water Board’s aim is to reduce the concentrations of phosphorus to 0.3 mg/L by the year 2000. By comparison, the average concentration of phosphorus in untreated sewage is approximately 12 mg/L. For nitrogen, concentrations will be reduced to 5–10 mg/L over this period. The average concentration of total nitrogen in raw sewage is 55 mg/L. According to Environment Protection Authority (1994), the costs of reducing phosphorus and nitrogen discharges from sewage treatment plants, will differ depending on the level of treatment used. For tighter discharge controls, abatement costs are expected to increase significantly with level of treatment. The estimated capital costs of removing phosphorus, using a range of biological nutrient removal and chemical phosphorus removal techniques is shown in Figure 5.

FIGURE 5. The capital cost per equivalent person of removing phosphorus ($/yr)
[source: Water Board Sewage Treatment Planning Sub-Branch (March 1991)
Table 8 shows the capital and operating costs of reducing phosphorus in sewage treatment plant discharges, based on cost estimates from a Water Board submission to the Pricing Tribunal, and Public Works estimates for Albury City Council (Environment Protection Authority, 1994). Reductions of phosphorus may be achieved by discharging effluent from sewage treatment plants to wetland systems, removing septic tanks and replacing them with reticulated sewers, minimising the use of phosphorus by households and industries that discharge waste to the sewerage system and by effluent re-use programs. It needs to be stated, though, that phosphate substitutes in detergents can also provide long term detrimental effects on the environment.

The aggregate costs for a range of options to protect the oceans, estuaries and beaches in Sydney, taking into account the various levels of treatment, with and without outfall, and effluent re-use for potable and non-potable purposes, is shown in Table 9. The present value costs range from $0.3 bn to $8.0 bn, depending on the type of treatment used. ‘Costs’ here represents the ‘present worth’ costs that are indicative of construction costs plus 20 years of operating costs in 1994 dollars. They are costs in addition to today’s wastewater service.

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<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>P &lt; 2 mg/L</td>
<td>374</td>
<td>60</td>
<td>–</td>
<td>–</td>
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<tr>
<td>P &lt; 1 mg/L</td>
<td>592</td>
<td>66</td>
<td>2390</td>
<td>66</td>
</tr>
<tr>
<td>P &lt; 0.3 mg/L</td>
<td>930</td>
<td>85</td>
<td>5290</td>
<td>285</td>
</tr>
<tr>
<td>P &lt; 0.1 mg/L</td>
<td>1087</td>
<td>115</td>
<td>8600</td>
<td>990</td>
</tr>
</tbody>
</table>


Table 8. The costs of reducing phosphorous in sewage treatment plant discharges

Today’s level of treatment at the major outfall plants is less than primary treatment. The cost of installing full secondary treatment at the coast needs to include upgrading the major plants to full primary treatment, bringing total cost of secondary treatment in the range of $3.5 to 4.0 bn. The high costs for non-potable re-use reflect the high costs of retrofitting existing developed areas of Sydney with a dual water supply. Consequently it is likely that non-potable effluent re-use will be limited to areas with large industrial users or recreational sites requiring irrigation such as parks, golf courses and playing fields, (Sydney Water, 1994).

By contrast, the cost data for Rouse Hill considered above (refer section 10.1) suggests that in new urban areas (or ‘greenfield’ sites), the cost of non-potable or potable re-use would be lower than the cost of treating sewage to very high quality prior to discharge.

10.4 Conclusion

Water re-use can be an economically attractive alternative source of water supply. While the implementation of wastewater re-use projects may be restricted due to quality considerations and tenuous public acceptance, it is possible to use wastewater
for appropriate purposes (irrigation, industry, flushing), and thereby release higher-quality water for other more exacting purposes. Furthermore, properly planned re-use of wastewater can be a cost-effective method of reducing environmental and health hazards which have been observed with traditional wastewater disposal practices.

**Table 9.** Options and present value costs for major and small coastal wastewater treatment plants

<table>
<thead>
<tr>
<th>Method</th>
<th>Treatment</th>
<th>Present value cost ($1994)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major coastal plants:</td>
<td>• Current treatment +</td>
<td>Included within currently planned Water Board expenditures</td>
</tr>
<tr>
<td></td>
<td>• improved grease removal</td>
<td></td>
</tr>
<tr>
<td>Small coastal plants:</td>
<td>• Current treatment</td>
<td></td>
</tr>
<tr>
<td>Major coastal plants:</td>
<td>• Current treatment +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• improved grease removal</td>
<td></td>
</tr>
<tr>
<td>Small coastal plants:</td>
<td>• Full primary treatment with high dilution outfall or secondary treatment</td>
<td>$0.3 billion</td>
</tr>
<tr>
<td>All coastal plants:</td>
<td>• Full primary treatment +</td>
<td>$2.0 billion</td>
</tr>
<tr>
<td></td>
<td>• effluent discharged through high dilution outfalls +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• source control on toxicants and floatables</td>
<td></td>
</tr>
<tr>
<td>All coastal plants:</td>
<td>• Full primary treatment +</td>
<td>$3.5 billion</td>
</tr>
<tr>
<td></td>
<td>• secondary treatment +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• disinfection +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• shore discharge at small coastal plants +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• source control on toxicants and floatables</td>
<td></td>
</tr>
<tr>
<td>All coastal plants:</td>
<td>• Full primary treatment +</td>
<td>$4.0 billion</td>
</tr>
<tr>
<td></td>
<td>• secondary treatment +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• disinfection +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• high dilution outfall +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• source control on toxicants and floatables</td>
<td></td>
</tr>
<tr>
<td>Re-use (non potable):</td>
<td>• Full primary treatment +</td>
<td>$4.0–8.0 billion</td>
</tr>
<tr>
<td></td>
<td>• secondary treatment +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• disinfection +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• source control on toxicants and floatables +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• distribution to users</td>
<td></td>
</tr>
<tr>
<td>Re-use all plant effluent (potable uses):</td>
<td>• Full primary treatment +</td>
<td>$6.0–8.0 billion</td>
</tr>
<tr>
<td></td>
<td>• secondary treatment +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• tertiary treatment +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• disinfection +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• membrane filtration +</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• distribution to users</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Sydney Water (1994a)*
As competition for available resources increases and regulatory limits on aqueous discharges tighten, integrated water management which embraces all potential water-supply sources, primary and reclaimed, and which produces multiple quality waters for various uses, will gain greater economic acceptance. However, any successful re-use of wastewater for water supply development must consider the overall perception of, and attitudes to, such projects. (Spulber and Sabbaghi, 1994 p. 171)

Implementation of effective wastewater strategies is complex. Each strategy must be assessed not only in terms of cost and pricing, but also ecological responses, environmental impacts, social consequences, technical feasibility and flexibility.

11. CURRENT AND PLANNED RE-USE OF TREATED SEWAGE IN AUSTRALIA

11.1 Sources Of Data

Information on current and planned re-use of treated sewage in Australia, presented in this section, is based on three main sources of data:

- the National Effluent Re-use Survey, a questionnaire-based survey of sewage treatment practices in all States and Territories in 1994
- a literature search through both electronic and paper based indexes, and
- interviews undertaken with water utility and state government representatives across Australia.

The National Effluent Re-use survey was undertaken by Melbourne Water on behalf of the former Water Technology Committee of AWRC. Responses were provided by State/Territory contact officers. Part 1 of the questionnaire provided a State/Territory summary. Part 2 provided information on individual treatment plants with throughput of 3 ML/day or greater. A copy of the questionnaire is given in Appendix D. Information was requested on existing and future sewage treatment practices, including percentage of water re-used. While this survey is a very valuable compilation, the data was in places incomplete and needed to be supplemented by assumptions in order to describe and predict trends at the state and nation-wide levels. Nevertheless the authors are satisfied that acceptably accurate data are given for the base year, 1994.

Published sources were searched through electronic indexes, including:

- Streamline (Australian; UWRAA database accessed online via the Internet)
- Water Resource Abstracts and Waterlit (International Databases accessed via CD-ROM)
- Infoseek and CARL Uncover (Internet Databases; attracting a fee for service)
- university library and special library catalogues (Australian and international; accessed via the Internet or by personal visits), and
- World Wide Web and Internet Listserv Lists, for example, Aquifer and electronic conferences (such as Ecotechnics ‘95).
Industry grey literature was also searched. Sources included:

- annual reports and strategic plans for water agencies and related companies (Australian and international)
- daily newspapers and current awareness journals (Australian and international), and
- water industry publications lists, consultancy reports (Australian and international).

Representatives from water authorities and related agencies throughout Australia were interviewed. Approximately 80 industry contacts were made.

These included:

- personal contacts with water industry representatives
- contact with various water utilities, environmental protection agencies, departments of heritage; conservation commissions etc, to speak to re-use/treatment technology/infrastructure planning units
- attendance at the AWWA 16th Federal Convention in Sydney, April, 1994, and
- visits to various sites, including the Water Authority of Western Australia; Murdoch University (Western Australia); ACT Electricity and Water; Department of Environment and Natural Resources (Adelaide); Department of Housing and Urban Development (Adelaide).

Sections 11.2 through 11.9 review current and planned sewage re-use in each state and territory. Section 11.10 then provides a national summary. Appendix C gives examples of current or planned wastewater re-use projects in Australia and overseas.

11.2 Australian Capital Territory

Canberra is served principally by the Lower Molonglo Water Quality Control Centre. The Queanbeyan Sewage Treatment Plant also discharges into ACT waters. Both these plants discharge a very high quality effluent. A significant increase in overall performance is unlikely to be practicable in the foreseeable future. However, there is pressure to cap pollutant loads at or about current levels. There is also increasing pressure to reduce the demand on potable water supplies, both from an economic and an environmental perspective, thus deferring (and possibly avoiding) the construction of an additional water supply dam. In this context, there is a growing emphasis on the potential for re-use. Land application, where the primary purpose is to dispose of effluent (rather than use it for some purpose) is not supported for widespread application in the ACT.

A long-standing facility using secondary treated sewage is the playing field irrigation at Duntroon Army Training College. The Southwell Park sewer mining scheme will supply irrigation water to Southwell Park, and possibly also the Yowani Country Club and Canberra racecourse. An experimental household level re-use scheme using six ACTEW employee’s houses is underway; and an additional six households are being retrofitted with dual reticulation schemes (ACT Electricity and Water 1994a, 1994b).
While re-use, particularly through local irrigation schemes is expected to increase, the overwhelming majority of ACT wastewater will continue to be discharged into the Molonglo River as highly treated effluent. This effluent contributes significantly to environmental flow in the Murrumbidgee River and is used for irrigated agriculture, urban water supply and recreation downstream of the ACT.

Current and expected future wastewater discharges within ACT for 1994, 2000 and 2020 are shown in Table 10. This table summarises the current expectations of future volumes, and the distribution of wastewater discharges to land and water, recorded in the National Effluent Re-use Survey, 1994.

**Table 10. ACT: current and expected future wastewater discharges (ML)**

<table>
<thead>
<tr>
<th>Water Discharged/Received:</th>
<th>1994</th>
<th>2000</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of water received:</td>
<td>33 000</td>
<td>40 000</td>
<td>50 000</td>
</tr>
<tr>
<td>Discharge to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>30</td>
<td>2 050</td>
<td>2 050</td>
</tr>
<tr>
<td>Direct Re-use</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>32 969</td>
<td>37 945</td>
<td>47 945</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Total volume discharge:</td>
<td>33 000</td>
<td>40 000</td>
<td>50 000</td>
</tr>
</tbody>
</table>

*Source: National Effluent Re-use Survey, 1994 (this report).*

### 11.3 New South Wales

Municipal sewerage service construction and operation is the responsibility of the Sydney Water Corporation in Sydney, Illawarra and Blue Mountains areas, Hunter Water Corporation in the Newcastle and the lower Hunter Valley, and local councils elsewhere. Householders or companies in private developments own and operate septic systems package treatment plants or bio-recycle systems. The Sydney Water Board provides sewerage facilities to 98% of the 1 295 000 properties in their service area (Environmental Protection Authority, New South Wales, 1993a).

Wastewater disposal in NSW can be divided into two main drainage divisions: the Murray-Darling Basin, and the coastal region. In both areas the increased treatment levels that would be necessary to maintain the ecological integrity of the aquatic environment, may make re-use options attractive in future.

In the Murray-Darling Basin health issues are a priority and the acceptability and value of re-use schemes is at least partly determined by their effect on the river. The environmental priority is to reduce nutrient loads during low-flow periods. Water discharged to inland waterways is primarily treated to secondary level.

Nutrient levels in the Nepean-Hawkesbury system are also a concern since extensive new urban developments are foreseen and the river water is used for urban water supply downstream. Sydney Water already treats much of the discharge to the Hawkesbury-Nepean catchment to advanced tertiary level. Options within this basin include:
• upgrading treatment levels and continued discharge of effluent to local receiving waters
• treatment and transfer to catchments west of the Blue Mountains
• re-use of sewage effluent for non-potable and potable re-use, and
• local small scale treatment.

Many of these options either directly or indirectly encourage re-use.

In the coastal region, discharge is frequently to coastal waters or rivers leading quickly to the ocean. There is less downstream use of these waters and less demand for water from irrigated agriculture. The coastal zone is more developed and industrialised so the main re-use markets lie in industry and residential areas.

Wastewater treatment levels (as a percentage of flow) for Sydney Water, Hunter Water, Public Works Department (PWD) country areas, and NSW total is shown in Table 11.

Recent changes in sewage treatment in NSW have been driven by environmental concerns about ocean discharge and pollution of rivers. For example, concerns about pollution of Sydney beaches has led to changes in the ocean outfall standards.

Table 11. NSW wastewater treatment levels 1994 (% of flow treated at level specified)

<table>
<thead>
<tr>
<th>Treatment Level</th>
<th>Sydney Water</th>
<th>Hunter Water</th>
<th>PWD country areas</th>
<th>Total NSW</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-Treatment</td>
<td>0.5</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Pre-Treatment</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Primary</td>
<td>85</td>
<td>0</td>
<td>0</td>
<td>58</td>
</tr>
<tr>
<td>Secondary</td>
<td>4.5</td>
<td>98</td>
<td>96</td>
<td>33</td>
</tr>
<tr>
<td>Tertiary/Advanced</td>
<td>10</td>
<td>1</td>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>


The ‘Clean Waterways’ Program, which extended from 1989–94, was aimed at improving sewage treatment to ensure safe, beneficial or environmentally acceptable disposal of effluent; improved sewage treatment plant reliability; safe beneficial use or environmentally acceptable disposal of treated residuals; encouragement of sewage source control and waste minimisation; and clearing of the backlog of unsewered properties (Sydney Water Board, 1994b).

The Clean Waterways Program resulted in substantial improvements, including: cleaner beaches, rivers and streams; cost-effective protection from sewage overflows; extending sewerage services; advances in source control; and advances in recycling sewage by-products (Sydney Water Board, 1994c). The Source Control Program of Clean Waterways was aimed at reducing the volume and variety of hard-to-treat substances such as heavy metals, organochlorines pesticides and phosphorus by imposing tighter requirements for on-site treatment. Industrial and commercial effluent makes up approximately 30% of the wastewater stream produced in Sydney (Philip, 1995). Industry now captures 300 wet tonnes/day of pollutants on site.
Companies have reduced discharges of licensed harmful substances to less than 20% of the 1991 standards (Sydney Water Board, 1994b).

Sydney beaches are now far less polluted by sewage, compared to the late 1980s. Treatment plant odours have been reduced and treatment plant reliability has increased. Sludge incineration and ocean disposal has ceased and 70% of sludge is recycled as a soil conditioner. Treated effluent is now disposed of 4km out to sea and is cleaner than when the Clean Waterways Program commenced (Sydney Water Board, 1994b). All four of Sydney’s ocean outfalls at North Head, Bondi, Malabar and Cronulla have been upgraded (Sydney Water Board, 1994b).

Options to further improve water quality and the environment in the coastal zone include:

- priority to upgrading smaller coastal treatment plants with primary treatment levels and nearshore discharges
- wastewater source control programs, with priority to improve the quality of domestic wastewater
- further treatment upgrades at the major coastal wastewater treatment plants
- ‘up-stream capture’ in the larger sewerage systems that discharge at the coast
- other non-discharge or flow reduction options (for example, placement of sewage treatment plants on the upper branches of the major coastal systems which would reduce the loading to downstream plants, provide opportunities for more localised non-potable re-use and reduce transportation costs of by-products such as sludge), and
- further re-use of water and water conservation strategies such as composting toilets in greenfield developments.

Estimated current and expected future wastewater discharges within NSW (derived from the 1994 Effluent Re-use Survey) for 1994, 2000 and 2020 are provided in Table 12. Discharges from Sydney Water alone are shown in Table 13.

### Table 12. NSW: current and expected future wastewater discharges (ML)

<table>
<thead>
<tr>
<th>Water Discharged/Received:</th>
<th>1994</th>
<th>2000</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of water received:</td>
<td>618 338</td>
<td>662 959</td>
<td>823 123</td>
</tr>
<tr>
<td>Discharge to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>28 198</td>
<td>33 427</td>
<td>46 970</td>
</tr>
<tr>
<td>Direct Re-use</td>
<td>8 710</td>
<td>23 851</td>
<td>29 178</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>138 293</td>
<td>157 593</td>
<td>234 147</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>443 137</td>
<td>448 088</td>
<td>512 828</td>
</tr>
<tr>
<td>Total volume discharge:</td>
<td>618 338</td>
<td>662 959</td>
<td>823 123</td>
</tr>
</tbody>
</table>


*Note:* Predicted future discharge rates from areas administered by the NSW Public Works Department were not available and have been estimated.

The National Effluent Re-use Survey, 1994 figures indicates that disposal to coastal waters is expected to become a smaller fraction of total discharge. The largest part of future increase in flows is expected to be disposed to inland rivers, especially the Hawkesbury-Nepean.
Non-potable residential re-use has been studied intensively in NSW. The Shoalhaven Pilot Study, for example, operated for 16 months, supplying 17 houses. The scheme has now concluded. The knowledge gained from the study led to a set of guidelines for residential re-use of wastewater (New South Wales Recycled Water Coordination Committee, 1993).

### Table 13. Sydney Water: current and expected future wastewater discharges (ML)

<table>
<thead>
<tr>
<th>Water Discharged/Received:</th>
<th>1994</th>
<th>2000</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of water received:</td>
<td>424 138</td>
<td>449 959</td>
<td>532 223</td>
</tr>
<tr>
<td>Discharge to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>1 098</td>
<td>2 741</td>
<td>3 470</td>
</tr>
<tr>
<td>Direct Re-use</td>
<td>5 110</td>
<td>18 251</td>
<td>23 178</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>50 025</td>
<td>61 322</td>
<td>103 577</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>367 905</td>
<td>367 645</td>
<td>401 998</td>
</tr>
<tr>
<td>Total volume discharge:</td>
<td>424 138</td>
<td>449 959</td>
<td>532 223</td>
</tr>
</tbody>
</table>


*Note:* These projections do not incorporate the expected effects of demand management programs on wastewater flow.

The Rouse Hill Development Area is to the north-west of Sydney. It falls within the Hawkesbury-Nepean catchment, which has already suffered algal problems due to the effects of urban wastewater and stormwater. The water supply for the area is Prospect Reservoir, which supplies a large area of western Sydney. Reducing overall demand on this reservoir is a priority. The Rouse Hill Sewage Treatment Plant will supply non-potable water through a dual reticulation system to residential users. These users are charged for this water at 20 c/kL compared with 65 c/kL for potable water, although the production cost of the recycled water is higher. Sydney Water expected to use 2920 ML/yr of treated wastewater in dual reticulation systems, in the Sydney area by the year 2020.

The National Effluent Re-use Survey, 1994 predicts significant industrial re-use in New South Wales, primarily in Wollongong and Newcastle. Re-use water is used for slag quenching at the Port Kembla steelworks. There are other potential re-use projects in the Port Kembla area and more than 50% of wastewater from the Wollongong treatment plant is predicted to go to industrial re-use by 2020. Reclaimed water is used for dust suppression at the Newcastle Coal Loader. Up to 5 ML/day of reclaimed water is used for coal washing, dust suppression and general washdown at the Stockton Borehole Colliery.

### 11.4 Northern Territory

Most of the Northern Territory’s coastal waters are in pristine condition, except the waters off Darwin, where there are localised pollution effects from the ocean outfalls from the sewage treatment plant. There are plans to upgrade the mechanical process at this plant and to re-use water for irrigation of ovals and other recreational areas on the Darwin Esplanade. Wastewater re-use for parks, gardens and recreation is already
practised Darwin, Katherine and Alice Springs. Non-potable re-use is being trialed at Black Point at ranger’s homes within the National Park. There is also interest among remote aboriginal communities in re-using treated greywater.

The NERS, 1994 results on wastewater flows for the NT were incomplete, as data was recorded for 1994 only. Wastewater flows in 2000 and 2020 were therefore assumed to increase in line with the expected population growth rate over this period (refer to Table 32). Estimated wastewater discharge within the Northern Territory for 1994 (derived from the NERS, 1994) 2000 and 2020 are shown in Table 14. Wastewater treatment levels (as a percentage of flow) for this state, are shown in Table 15.

### Table 14. NT: current and expected future wastewater discharges (ML)

<table>
<thead>
<tr>
<th>Water Discharged/Received:</th>
<th>1994</th>
<th>2000</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of water received:</td>
<td>15 030</td>
<td>16 000</td>
<td>20 000</td>
</tr>
<tr>
<td>Discharge to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>1 250</td>
<td>1 600</td>
<td>2 400</td>
</tr>
<tr>
<td>Direct Re-use</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>1 100</td>
<td>1 100</td>
<td>1 100</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>9 090</td>
<td>13 300</td>
<td>11 723</td>
</tr>
<tr>
<td>Total volume discharge:</td>
<td>11 440</td>
<td>16 000</td>
<td>15 523</td>
</tr>
</tbody>
</table>


*Note:* Total volume of received water differs from total volume discharged due to high evaporative losses during treatment. This is particularly the case in open (versus closed) treatment facilities. A similar outcome is evident in Table 16 and Table 23 (following).

### Table 15. NT: wastewater treatment levels in 1994 (%)

<table>
<thead>
<tr>
<th>Treatment Level:</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No treatment</td>
<td>6</td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>0</td>
</tr>
<tr>
<td>Primary</td>
<td>12</td>
</tr>
<tr>
<td>Secondary</td>
<td>82</td>
</tr>
<tr>
<td>Tertiary/Advanced</td>
<td>0</td>
</tr>
</tbody>
</table>


#### 11.5 Queensland

Wastewater volumes in Queensland are increasing as the population is growing rapidly, particularly in the South-East.

The South-Eastern Region bounded by the New South Wales Border to the Noosa River and west to the Great Dividing Range comprises only 1.3% of the land area of Queensland, but contains 63% of Queensland’s population. By 1993, 304 000 ML/yr of wastewater was produced at the 213 treatment plants within this area. The wastewater treatment plants are at or near capacity in South-East Queensland (Gardner
et al., 1993). In recent times, some 90% of effluent has been disposed to inland or marine waters (Bryan et al., 1994).

Established wastewater discharges within Queensland for 1994 (derived from the NERS, 1994) are provided in Table 16. Wastewater treatment levels (as a percentage of flow) for Queensland are shown in Table 17.

Table 16. Queensland: current and expected future wastewater discharges (ML)

<table>
<thead>
<tr>
<th>Water Discharged/Received:</th>
<th>1994</th>
<th>2000</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of water received:</td>
<td>305 000</td>
<td>337 635</td>
<td>472 689</td>
</tr>
<tr>
<td>Discharge to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>30 660</td>
<td>33 941</td>
<td>47 517</td>
</tr>
<tr>
<td>Direct Re-use</td>
<td>1 220</td>
<td>1 351</td>
<td>1 891</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>31 810</td>
<td>35 214</td>
<td>49 299</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>240 320</td>
<td>266 034</td>
<td>372 446</td>
</tr>
<tr>
<td>Total volume discharge:</td>
<td>304 010</td>
<td>336 540</td>
<td>471 153</td>
</tr>
</tbody>
</table>


In the South-Eastern Region, land disposal amounted to 32 000 ML. in 1993. Land availability dictates the total volumes that can be disposed of in this way. An estimated 100 000 ML/yr is the uppermost estimate of possible disposal to land. Most land disposal schemes currently in operation are hydraulically and nutritionally overloaded. Land disposal is expected to increase markedly during the remaining part of the decade. However, the wastewater will need to be re-used on land, rather than ‘disposed to land’ due to the areas required for disposal.

Table 17. Queensland: wastewater treatment levels in 1994 (%)

<table>
<thead>
<tr>
<th>Treatment Level:</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No treatment</td>
<td>0</td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>0</td>
</tr>
<tr>
<td>Primary</td>
<td>15</td>
</tr>
<tr>
<td>Secondary</td>
<td>81</td>
</tr>
<tr>
<td>Tertiary/Advanced</td>
<td>4</td>
</tr>
</tbody>
</table>


There is the potential for up to 30% of Queensland’s total effluent to be re-used on land. The problems encountered by Queensland operators of land disposal systems include: climatic conditions (such as extended wet season), pipe blockages, pump breakdowns and lack of available land. Land availability can be tackled by land use planning, re-zoning and promoting effluent re-use for agricultural irrigation (Gardner et al., 1993).

Research to date has shown that climatic and site conditions favour the utilisation of artificial wetlands in Queensland (Simpson, 1994). A review of the Queensland Guidelines for Planning and Design of Sewerage Schemes (1991/2) called for the
investigation of artificial or constructed wetlands for wastewater treatment. The Queensland Department of Primary Industries has initiated an Artificial Wetlands Research Program. Ten artificial wetlands have been constructed for enhanced treatment of treated effluent.

There is widespread re-use for irrigation of parklands and recreational areas throughout Queensland. Secondary or tertiary treated effluent is used to water resort gardens and golf courses on 15 islands in the Great Barrier Reef chain and in the coastal cities of Mulgrave Shire, Thuringowa, Townsville, and Yeppoon. Sludge is also re-used, following stockpiling.

The Great Barrier Reef Marine Park Authority, in conjunction with the Queensland Government has encouraged the re-use of treated effluent by coastal cities. Many coastal local governments now have re-use policies and some have ceased ocean discharges altogether (Brodie, 1994).

The Queensland Government’s Integrated Catchment Management Program aims to reduce terrestrial losses of sediments and nutrients from Queensland catchments (Brodie et al., 1994). Since 1991, the Great Barrier Reef Marine Park Authority has been funded by the Commonwealth Government to implement a Water Quality Research and Monitoring Program. The focus is to examine the effect of increased nutrient and sediment loads on phytoplankton, coral and seagrasses within the Great Barrier Reef Marine lagoon (Steven and Brodie, 1994). In addition, since 1991, the Great Barrier Reef Marine Park Authority has required tertiary (nutrient reduction) treatment of direct sewage discharges into the Park. Existing operations were given a five year compliance period. New operations need to comply from inception. Most resorts now either do not discharge at all into the park or have adopted tertiary treatment of effluent. A total of 14 out of 19 of the island resort treatment systems were operating at a satisfactory level as at June 1994, with 18 months of the compliance period to go. During heavy rainfall events, resort islands are allowed overflow discharge. Most resorts have implemented irrigation schemes due to the scarcity or high cost of potable water supplies (Brodie, 1994).

11.6 South Australia

The current and future expected wastewater discharges within South Australia to land and water bodies is shown in Table 18.

Table 18. SA: current and expected future wastewater discharges (ML)

<table>
<thead>
<tr>
<th>Water Discharged/Received:</th>
<th>1994</th>
<th>2000</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of water received:</td>
<td>104 726</td>
<td>107 683</td>
<td>112 902</td>
</tr>
<tr>
<td>Discharge to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>6 819</td>
<td>7 134</td>
<td>7 350</td>
</tr>
<tr>
<td>Direct Re-use</td>
<td>2 881</td>
<td>2 881</td>
<td>2 881</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>1 548</td>
<td>1 548</td>
<td>1 548</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>93 478</td>
<td>96 120</td>
<td>101 123</td>
</tr>
<tr>
<td>Total volume discharge:</td>
<td>104 726</td>
<td>107 683</td>
<td>112 902</td>
</tr>
</tbody>
</table>

Wastewater treatment levels (as a percentage of flow treated to specific levels) is reported in Table 19.

**Table 19.** SA: wastewater treatment levels in 1994 (%)

<table>
<thead>
<tr>
<th>Treatment Level</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No treatment</td>
<td>0</td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>0</td>
</tr>
<tr>
<td>Primary</td>
<td>0</td>
</tr>
<tr>
<td>Secondary</td>
<td>96</td>
</tr>
<tr>
<td>Tertiary/Advanced</td>
<td>4</td>
</tr>
</tbody>
</table>

*Source: National Effluent Re-use Survey, 1994 (this report).*

In the Adelaide region four wastewater treatment plants at Bolivar, Christies Beach, Glenelg and Port Adelaide discharge treated wastewater to the Gulf of St Vincent and the Port River. Discharges from these areas currently exceed the National Water Quality Management Strategy (1992) water quality guidelines. Consequently, the Engineering and Water Supply Department (E&WS) (1994c) developed a Draft Environmental Improvement Program to reduce or eliminate impacts of wastewater disposal on the marine environment. The four principles identified were:

- summer re-use of treated effluent
- improved dilution and dispersion of treated effluent disposed to the marine environment during winter
- nutrient reduction processes and expansion of summer re-use schemes, and
- 100% re-use where practical and economical.

The total capital cost for full land-based disposal for the Adelaide region was estimated at $477m. Due to the high total cost for full re-use, the program was divided into two stages for each plant. The highest benefit to the environment per dollar spent is the “Nutrient Reduction” option whereby $85m would be invested to reduce the nutrient loads discharged to the Gulf of St Vincent by 80% (Engineering and Water Supply, 1994c).

Most of South Australia’s inland waters have little or no flow in summer, and therefore no capacity to dilute discharges during these months. Water quality objectives and classifications have been created bearing this in mind. Sewage effluent was identified in 1992 along with irrigation drainage and stormwater as a major source of pollution in the South Australian section of the Murray River. Land disposal, irrigation of golf courses and discharge of septic tank effluent at peak levels of river flow have reduced the nutrient flow into the Murray within South Australian borders, especially during low-flow periods. Funding for the schemes was provided by the Commonwealth Government Healthy Catchments Program (Department of Environment and Land Management, 1993).

Wastewater disposal practices in South Australia are summarised in Engineering and Water Supply Department (1994) and Department of Environment and Land Management (1993). The goal of the “Country Wastewater Treatment Plants Reclaimed Water Management Plan” (Engineering and Water Supply Department, 1994b), is to minimise the impact of discharge on the environment. A summary of preferred wastewater
treatment options for 15 country sites is provided in Table 20. The estimated capital and operating costs of implementing these options are also provided.

Table 20. Country wastewater treatment options for South Australia

<table>
<thead>
<tr>
<th>Plant</th>
<th>Design Population</th>
<th>Preferred Option</th>
<th>Capital Cost *</th>
<th>Operating Cost +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alinga</td>
<td>5000</td>
<td>Total land-based disposal</td>
<td>$5 000 000</td>
<td>$75 000</td>
</tr>
<tr>
<td>Angaston</td>
<td>2300</td>
<td>Use reclaimed water for irrigation</td>
<td>$600 000</td>
<td>$24 000</td>
</tr>
<tr>
<td>Bird in Hand</td>
<td>16000</td>
<td>Summer reuse/winter discharge</td>
<td>$325 000</td>
<td>$12 360</td>
</tr>
<tr>
<td>Gumeracha</td>
<td>2500</td>
<td>Continuous discharge to pine plantation</td>
<td>$200 000</td>
<td>$5 000</td>
</tr>
<tr>
<td>Hahndorf</td>
<td>4600</td>
<td>Enhanced treatment and continued discharge</td>
<td>($3 150 000)</td>
<td>($180 000)</td>
</tr>
<tr>
<td>Heathfield</td>
<td>10000</td>
<td>Enhanced treatment and continued discharge</td>
<td>$1 172 000</td>
<td>$155 000</td>
</tr>
<tr>
<td>Mannum</td>
<td>3600</td>
<td>Total reuse for irrigation</td>
<td>($458 000)</td>
<td>($14 000)</td>
</tr>
<tr>
<td>Millicent</td>
<td>7500</td>
<td>Chemical phosphorus removal and continued discharge</td>
<td>$60 000</td>
<td>$80 000</td>
</tr>
<tr>
<td>Mount Burr</td>
<td>1250</td>
<td>Continuous discharge to pine plantation</td>
<td>$75 700</td>
<td>$6 100</td>
</tr>
<tr>
<td>Mount Gambier</td>
<td>41000</td>
<td>Continued discharge to ocean</td>
<td>($6 000 000)</td>
<td>($250 000)</td>
</tr>
<tr>
<td>Murray Bridge</td>
<td>16000</td>
<td>Land-based disposal</td>
<td>($2 100 000)</td>
<td>($12 000)</td>
</tr>
<tr>
<td>Myponga</td>
<td>250</td>
<td>Total reuse for irrigation</td>
<td>$190 000</td>
<td>$1 060</td>
</tr>
<tr>
<td>Nangwarry</td>
<td>1250</td>
<td>Continuous disposal to pine plantation</td>
<td>$103 400</td>
<td>$8 700</td>
</tr>
<tr>
<td>Port Lincoln</td>
<td>20000</td>
<td>Intermittent activated sludge with nitrogen reduction. Discharge unchlorinated reclaimed water to Bay</td>
<td>($5 000 000)</td>
<td>($80 000)</td>
</tr>
<tr>
<td>Victor Harbour</td>
<td>8000</td>
<td>Summer reuse for irrigation/winter discharge to river plus upgrade for additional capacity and nutrient reduction</td>
<td>$5 271 000</td>
<td>$130 000</td>
</tr>
</tbody>
</table>

Source: Engineering and Water Supply Department (1994)
*Based on projected population growth over 20 years (generally)
+Indicative values only. Bracketed values indicate that plant has been constructed.

Cost-effective land-based disposal systems will be adopted, rather than encouraging enhanced nutrient removal processes, and continued discharge to sensitive water environments (which still occurs from the Murray Bridge and Mannum). Land-based disposal schemes have are being implemented at the Murray Bridge and Mannum plants. Where land-based treatment is not economically viable, plants are being upgraded (for example, Hahndorf and Heathfield). The Hahndorf plant discharges to the Onkaparinga River. The Heathfield plant is located in an area where land based disposal is impractical.

Water-quality monitoring programs are in place where discharge to water bodies will continue in the future, or where discharge to water bodies is continuing while alternat-
ive disposal options are being explored (for example, Millicent and Bird in Hand). The Millicent treatment plant discharges into a drain flowing into Lake Bonney which also receives wastewater from a local pulp mill. A water-quality monitoring program has been implemented to assess the impact of the current discharge on the Sturt River and treatment level required. Reclaimed water from the Bird in Hand wastewater treatment plant is discharged into the headwaters of Dawesley Creek. An economic assessment of future operating strategies, has compared the continued discharge into the Creek with a range of land based disposal options. Total land based disposal appeared to be considerably more expensive than upgrading the treatment process. The most effective option appeared to be the option to discharge to the creek during the non-irrigation period and to use the remainder of the reclaimed water for irrigation of a woodlot. The present value cost of this wastewater treatment option was estimated to be $325 000 (refer Table 20).

At Alinga, sewage used to be tankered to the Christies Beach sewerage system for treatment as this was a cheaper alternative than construction of a local treatment plant. As the population grew, tankering became too expensive. A new treatment plant is being constructed at Alinga with an initial design capacity of 5000 EP. The cost of the treatment plant and storage and reticulation facilities for a land-based disposal scheme based upon the irrigation of vineyards is estimated to be approximately $5.5 million, which includes the cost to buy the land for irrigation and establish and equip a vineyard (Engineering and Water Supply Department, 1994).

Woodlots are irrigated with treated effluent at the Berri Winery, at Glossop, South Australia. The use of treated wastewater to irrigate sports fields and golf courses is a widespread practice in rural towns.

Vegetable production and irrigation of pastures in the Virginia Triangle represents the best opportunity for use of treated effluent for agricultural irrigation in South Australia. The abstraction of water for irrigation in this area is above the sustainable yield of the aquifer which is the main current source of water supply. There is a proposal to build a pipeline from the Bolivar Treatment Plant to the area. This could both supply water directly to agricultural users and be used to recharge the aquifer during periods of low water demand. The advantages of the scheme include the reduction in nutrient discharge from the Bolivar Plant to the Gulf of St Vincent, a reduction in withdrawals from the aquifer to a sustainable level, and the maintenance of the horticultural activity in the Virginia Triangle. Economic evaluation suggests that the project is viable (Kinhill, 1993).

New Haven is a development of 67 houses currently under construction by the Multi Function Polis (MFP) Adelaide. The housing will feature a dual reticulation scheme, where greywater will be re-used by householders on their gardens. The scheme also incorporates stormwater re-use. Sludge is used for fertiliser by vegetable farmers in the Virginia Triangle.

11.7 Tasmania

Wastewater re-use in Tasmania has been limited because there are generally adequate supplies of water. Responses to the National Effluent Re-use Survey, 1994 suggested
that the major obstacle to increased re-use has been the lack of markets for reclaimed water. However, emerging concern for coastal water quality has led to the production of a State Water Quality Policy including wastewater re-use guidelines. Elevated nutrients from sewage and urban and agricultural run-off affects water quality in the Derwent estuary (Zann, 1995).

Effluent is now re-used to irrigate golf courses and municipal gardens in Riverside. Brighton Council has a 3300 m³/d licensed flow of which 200 m³/d is re-used in dry periods. Sorrel Council is proposing to re-use effluent for irrigation. Clarence City Council is examining total re-use for irrigation by the year 2010. The town of New Norfolk has developed a recreational wetland between its sewage treatment plant and the nearby Derwent River.

Estimated current and expected future wastewater discharges within Hobart are shown in Table 21. NERS results on wastewater flows for Tasmania were incomplete, as estimates were recorded for Hobart only. The estimated wastewater flows for Tasmania (in total) were consequently extrapolated from the Hobart data set. These estimates are shown in Table 22.

Table 21. Hobart: current and expected future wastewater discharges (ML)

<table>
<thead>
<tr>
<th>Water Discharged/Received:</th>
<th>1994</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of water received:</td>
<td>8 200</td>
<td>10 250</td>
</tr>
<tr>
<td>Discharge to:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Direct Re-use</td>
<td>0</td>
<td>1 500</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>0</td>
<td>8 750</td>
</tr>
<tr>
<td>Total volume discharge:</td>
<td>8 200</td>
<td>10 250</td>
</tr>
</tbody>
</table>


Hobart City Council is examining re-use for an industrial supply and for irrigation of playing fields and a botanical garden.

Table 22. Tasmania: current and expected future wastewater discharges (ML)

<table>
<thead>
<tr>
<th>Water Discharged/Received:</th>
<th>1994</th>
<th>2000</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of water received:</td>
<td>50 300</td>
<td>52 552</td>
<td>60 435</td>
</tr>
<tr>
<td>Discharge to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Direct Re-use</td>
<td>910</td>
<td>955</td>
<td>1 093</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>14 390</td>
<td>15 031</td>
<td>17 290</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>35 000</td>
<td>36 566</td>
<td>42 052</td>
</tr>
<tr>
<td>Total volume discharge:</td>
<td>50 300</td>
<td>52 552</td>
<td>60 435</td>
</tr>
</tbody>
</table>

Note: The breakdown of wastewater flow data into the direct re-use, inland waters and coastal waters categories, has been estimated from survey results on total discharge and follow-up discussions with relevant Tasmanian departments.
11.8 Victoria

Wastewater services in Victoria are provided by Melbourne Water, Regional Water Authorities, Water Boards, Municipal Councils, the Commonwealth, and other bodies. The total volume of wastewater treated is 518 000 ML (1993). Effluent is discharged to ocean outfalls, streams or lakes and by evaporation. Sixty-eight per cent of treated wastewater is discharged to coastal waters; 15% is discharged to inland waterways and 17% is applied to land. Water is re-used on racetracks and golf courses, and within the Werribee Treatment Plant.

Estimated current and expected future wastewater discharges within Victoria are shown in Table 23. Wastewater treatment levels, for Victoria, as a percentage of flow are given in Table 24.

Table 23. Victoria: current and expected future wastewater discharges (ML)

<table>
<thead>
<tr>
<th>Water Discharged/Received:</th>
<th>1994</th>
<th>2000</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of water received:</td>
<td>507 173</td>
<td>556 625</td>
<td>664 300</td>
</tr>
<tr>
<td>Discharge to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>82 191</td>
<td>99 748</td>
<td>135 302</td>
</tr>
<tr>
<td>Direct Re-use</td>
<td>958</td>
<td>1 345</td>
<td>12 905</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>74 071</td>
<td>46 306</td>
<td>30 000</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>326 580</td>
<td>385 901</td>
<td>460 793</td>
</tr>
<tr>
<td>Total volume discharge:</td>
<td>483 800</td>
<td>533 300</td>
<td>639 000</td>
</tr>
</tbody>
</table>


Most of the coastal discharges are from the Melbourne, Geelong, and LaTrobe Valley areas. Approximately 90% of the secondary treated effluent generated in Melbourne (330 GL/yr) is from the Western Treatment Plant at Werribee, which is discharged into Port Phillip Bay, and the South-Eastern Purification Plant at Carrum which is discharged into the Bass Strait. The remaining 10% is treated by 27 local treatment plants throughout Melbourne (Skinner and Vass, 1995).

Eight per cent of total wastewater disposal to ocean, and the bulk of non-metropolitan effluent disposal, is contributed by Geelong’s Black Rock plant (approximately 18 800 ML) and the LaTrobe Valley Ocean Outfall (14 000 ML).

Table 24. Victoria: wastewater treatment levels in 1994 (%)

<table>
<thead>
<tr>
<th>Treatment Level:</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No treatment</td>
<td>0.2</td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>3.8</td>
</tr>
<tr>
<td>Primary</td>
<td>0</td>
</tr>
<tr>
<td>Secondary</td>
<td>55.0</td>
</tr>
<tr>
<td>Tertiary/Advanced</td>
<td>41.0</td>
</tr>
</tbody>
</table>


Table 25 gives details on the treatment levels according to the type of discharge.
Table 25. Wastewater treatment processes and disposal in Victoria

<table>
<thead>
<tr>
<th>Disposal to:</th>
<th>Level of Treatment:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trade</td>
</tr>
<tr>
<td>Ocean and Coastal</td>
<td>1</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>1</td>
</tr>
<tr>
<td>Land</td>
<td>–</td>
</tr>
<tr>
<td>Land</td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
</tr>
</tbody>
</table>

*Note:* The two Commonwealth Government treatment plants (at Puckapunyal and Bandiana) are included in the above figures (Environmental Protection Authority and Department of Conservation and Natural Resources Victoria.

There is concern that current wastewater disposal systems are not sustainable. For example, Port Phillip Bay is almost enclosed, being surrounded on its northern and eastern shores by city and suburban Melbourne (population 2.6m). Exchange time of the bay waters with the ocean is approximately one year. Restricted flushing has implications for management of water quality and the ecology of the waters, which receive stormwater runoff and treated sewage effluent. The contribution of stormwater to pollution loads is considerable. Most metal and organic toxicants are precipitated close to the entry of the freshwater discharges into the saline bay. The sedimentation of toxicants and tidal flushing reduces toxicant levels in the water to low, if not undetectable levels (Murray, 1994). The Port Phillip Bay Environmental Study has concluded that the ecology of the Bay has adapted to the increased nutrient loadings since European settlement. Ongoing monitoring of nutrients in the bay will determine if this is sustainable. The capital costs of changing effluent disposal practices would be considerable.

The Nutrient Management Strategy for Victorian Inland Waters (State Government of Victoria, 1995) indicated that most waterways, excluding those in East Gippsland, carry excessive nutrient loads. Consequently, 74 treatment plants which are discharging to inland streams should be upgraded to tertiary treatment or full re-use schemes.

The Victorian Government aims to encourage the re-use of treated effluent on land where practical, and to promote treatment options which provide the best potential for re-use and ecological sustainability. If wastewater disposal onto land is not practical, wastewater management plans will need to be submitted by water authorities, indicating options which maximise wastewater re-use and minimise adverse nutrient impacts on inland waterways. The Environment Protection Authority (Victoria) will work with water authorities where necessary, to revise discharge licenses to incorporate performance improvement programs over seven years, to ensure state environment protection policy objectives are fulfilled (State Government of Victoria, 1995). Over the next 5 years projected changes in disposal practices throughout Victoria are expected to include:

- increase in disposal to land from 82 200 to 99 800 ML/yr
- decrease in discharge to inland waterways from 70 500 to 43 900 ML/yr, and
- an additional disposal to Bass Strait of 12 800 ML/yr. This increase is expected to be the result of Dandenong South Treatment Plant being redirected from Dandenong Creek to Bass Strait via the South Eastern Purification Plant.
A significant volume of water from the Western Treatment Plant at Werribee is used for irrigated pastures and overflow systems, with 59 000 ML/yr going to these uses. Despite expected increases in the total volume of effluent disposed from this plant by the year 2020 (from 159 000 to 259 150 ML/yr), the volume of water going to irrigation is not expected to increase over this period.

Poor management practices within some re-use irrigation schemes, particularly in the high rainfall areas, resulted in the Victorian EPA issuing 20 towns with emergency discharge approval in 1993. Consequently, an extra 100 ML of wastewater was discharged to waterways. These problems can be avoided in future through upgraded design and operational procedures. The Shepparton Regional Water Authority operates such a scheme.

Many country towns in Victoria already re-use their wastewater. Wastewater is either re-used directly, for irrigation or indirectly before disposal to streams or lakes. There are 70 towns which currently re-use all of their treated effluent and another 38 that re-use some of their effluent. Treated wastewater is used to irrigate pastures at Shepparton, Tatura, and Melton. Woodlots, irrigated with treated wastewater, have been established at Mildura, Portarlington, and Winchelsea. Irrigation of recreational areas using treated effluent is practised in Craigieburn and Melbourne. Commercial Polymers Pty Ltd uses treated wastewater to supplement water supply for use in the cooling tower basin in its polyethylene resin production process. A pilot groundwater recharge project, using treated effluent was conducted in 1978 at Carrum.

Considerable scope exists throughout Victoria for additional use of treated wastewater for both agricultural and non-agricultural activities. It is expected that 19 towns will implement total re-use over the next 5 years (Environmental Protection Authority and Department of Conservation and Natural Resources, 1994). Research conducted at Werribee has investigated the potential for growing Jerusalem artichokes with treated wastewater. Four households in Melbourne have participated in a trial non-potable wastewater re-use scheme (Lechte et al., 1995).

11.9 Western Australia

Approximately 84% of Western Australia’s wastewater flow is within the Perth Region. Wastewater flows from the South West Region account for a further 6% of total flows. The remaining 10% originates from country areas, and from minor sources (Water Authority of Western Australia, 1992, 1994e, 1994f).

Estimated current and expected future wastewater discharge volumes for Western Australia are shown in Table 26. These estimates are consistent with state-wide extrapolations of the data provided in the Wastewater 2040 Study for Perth and the south west region of Western Australia (Water Authority of Western Australia, 1994e). Wastewater treatment levels, for Western Australia, as a percentage of flow, are shown in Table 27. Treatment levels and disposal outlets or Perth and Western Australian country areas is discussed below.
Table 26. WA: current and expected future wastewater discharges (ML/yr)

<table>
<thead>
<tr>
<th>Water Discharged/Received:</th>
<th>1994</th>
<th>2000</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of water received:</td>
<td>93 812</td>
<td>112 014</td>
<td>198 422</td>
</tr>
<tr>
<td>Discharge to:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>12 790</td>
<td>16 317</td>
<td>28 903</td>
</tr>
<tr>
<td>Direct Re-use</td>
<td>3 382</td>
<td>17 046</td>
<td>15 838</td>
</tr>
<tr>
<td>Inland Waters</td>
<td>875</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Coastal Waters</td>
<td>76 765</td>
<td>78 651</td>
<td>153 681</td>
</tr>
<tr>
<td>Total volume discharge:</td>
<td>93 812</td>
<td>112 016</td>
<td>198 422</td>
</tr>
</tbody>
</table>


Perth’s wastewater flow is discharged to ocean. Forty nine per cent is treated to secondary level and 35 per cent is primary treated. Only 0.9% of the wastewater is disposed to land in the Perth metropolitan area. This contrasts with the country areas where 68% of the wastewater is disposed to land and 13% is re-used (Water Authority of Western Australia 1994e; 1994f).

In terms of health standards, swimming beaches in Perth and Bunbury are monitored for faecal coliform levels by the Western Australian Health Department (fortnightly in summer and monthly in winter). The results of monitoring are generally within the primary contact Guidelines for Fresh and Marine Waters (ANZECC, 1992). Ocean outfalls are licensed by the WA Environmental Protection Authority.

Table 27. WA: wastewater treatment levels in 1994 (%)

<table>
<thead>
<tr>
<th>Treatment Level:</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No treatment</td>
<td>0</td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>0</td>
</tr>
<tr>
<td>Primary</td>
<td>36</td>
</tr>
<tr>
<td>Secondary</td>
<td>64</td>
</tr>
<tr>
<td>Tertiary/Advanced</td>
<td>0</td>
</tr>
</tbody>
</table>


The Perth and South-West Region are undergoing a large sewerage infill program. Only 60% of urban, commercial and industrial developments currently have a treatment and disposal service. Most unsewered areas use septic tanks which come under the control of the Western Australian Health Department.

Alternatives for disposal of Perth wastewater have been investigated as part of the Wastewater 2040 initiative conducted by the Water Authority of Western Australia in consultation with the communities of Perth and the South West region. The alternatives investigated included: discharge to rivers and water courses, wetlands, land application and agro-forestry, groundwater recharge, injection into coastal dunes to reduce salt water intrusions, and direct and indirect potable re-use. Each option was investigated from the standpoint of health standards, social, environmental, technical and economic perspectives (Water Authority of Western Australia 1994b, 1994d, 1994e, 1994f).
On the Swan Coastal Plain, abundant fresh groundwater is available, which is extracted free of charge for use in residential gardens and on municipal recreational areas. (Water Authority of Western Australia, 1994f). There is concern about nutrient flows to unconfined superficial aquifers. This means that urban irrigation and land disposal is not considered advisable in many locations. For example, while woodlots established within the Gnangara Mound area could conceivably utilise treated wastewater from Perth’s northern suburbs treatment plants, this is not desirable since the aquifer supplies substantial amounts of Perth’s potable water supply. The sandy soils on Perth’s Swan Coastal Plain do not hold phosphorus well, and woodlots usually only account for 20% phosphorus removal from the soil, where treated effluent has been applied (Water Authority of Western Australia, 1994f). Lack of suitable soils close to the existing sewage treatment plants preclude the establishment of some re-use schemes. Conversely, pipeline and pumping costs may be excessive, for example a scheme examined for re-using Perth wastewater for woodlots or agricultural production 260 km away near Merredin (Water Authority of Western Australia, 1994e).

Re-use for irrigation is not allowed in the vicinity of Perth (Water Authority of Western Australia, 1994e). However, in the developed urban areas, groundwater is already both nutrient-rich, and otherwise contaminated. Fertiliser applications and other activities generating groundwater pollution continue. At Palmyra in Perth, a retirement village has been the basis of a household level non-potable wastewater re-use project.

The Wastewater 2040 Discussion Paper identified industrial demand as a major re-use market. There is potential for expansion of industrial re-use schemes in the Kwinana Industrial Area as most of the groundwater is already utilised and scheme water is relatively expensive. The Water Authority of Western Australia, funded by the Federal Government’s “Building Better Cities Programme” has established a $1.85m project to demonstrate the feasibility of treating primary effluent to produce water for industrial use. Some of the technologies demonstrated include chemically assisted sedimentation and activated sludge followed by lime softening or microfiltration (Water Authority of Western Australia, 1994d).

The proposed Compact Steel Plant would be a potentially large user of reclaimed wastewater. The effluent would be supplied from the Cape Peron Pipeline and used as cooling water. Two thirds of the water would evaporate during the cooling process, and the remaining third, with a high concentration of suspended elements and heavy metals, would be delivered back into the pipeline (Water Authority of Western Australia, 1994f). If the project is approved, it is expected to increase the State’s reuse of treated municipal wastewater from an average of 8 ML/d (2.1%) to 41.6 ML/d (about 10%) (Water Authority of Western Australia, 1994f). The effects on the discharge of contaminants to the ocean would, however, be minimal, though these would remain within the Australian Guidelines.

Hartley et al., (1991) compared the use of primary sewage effluent from the Woodmans Point Wastewater Treatment Plant in industrial cooling towers at Kwinana with that of municipal scheme water. The cost of supplying potable scheme water, at 63.6c/kL, was 6.5% lower than supplying treated wastewater. However this difference
was considered negligible given the uncertain nature of the estimates. Differences in discharge costs were not considered.

Eighty per cent of the South-West Region’s wastewater is disposed to land (excludes Perth). Some 35 towns in the drier regions of the State discharge to land. For 6 months of the year this flow is 8 ML/day. Most of this flow is re-used on municipal parks, gardens and golf courses.

Discharge of effluent to King George Sound at Albany ceased in 1995. Under a new scheme, all the town’s treated effluent is being used to irrigate a *Eucalyptus globulus* woodlot. Further opportunities for reticulating parks, golf courses and gardens adjacent to wastewater treatment plants are being explored in the South-West Region of Western Australia (for example, Halls Head, Australind, Yunderup, and Caddadup).

### 11.10 National Outlook For Re-use

#### 11.10.1 Population growth

Total wastewater flow may be expressed as a function of the population and per capita flow generated. Changes in one or both of these factors will subsequently affect total flows.

Although the rate of increase varies from state to state and city to city, in general the population of Australia is increasing, as shown in Table 28. Based on these population predictions, estimated wastewater flow volumes (for each state, and for Australia, in total) may be derived (Table 29).

**Table 28.** Projected populations of Australian States and Territories (’000s)

<table>
<thead>
<tr>
<th>Year</th>
<th>NSW</th>
<th>QLD</th>
<th>VIC</th>
<th>SA</th>
<th>WA</th>
<th>TAS</th>
<th>NT</th>
<th>ACT</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>6043</td>
<td>3151</td>
<td>4487</td>
<td>1470</td>
<td>1697</td>
<td>479</td>
<td>179</td>
<td>304</td>
<td>17844</td>
</tr>
<tr>
<td>2000</td>
<td>6281</td>
<td>3419</td>
<td>4599</td>
<td>1493</td>
<td>1814</td>
<td>489</td>
<td>191</td>
<td>329</td>
<td>18978</td>
</tr>
<tr>
<td>2010</td>
<td>6698</td>
<td>3918</td>
<td>4791</td>
<td>1532</td>
<td>2027</td>
<td>506</td>
<td>215</td>
<td>375</td>
<td>20405</td>
</tr>
<tr>
<td>2020</td>
<td>7143</td>
<td>4490</td>
<td>4992</td>
<td>1573</td>
<td>2265</td>
<td>524</td>
<td>241</td>
<td>427</td>
<td>21940</td>
</tr>
</tbody>
</table>

*Source:* Bureau of Immigration Multicultural and Population Research, 1994

**Table 29.** Wastewater flow at population growth rate (GL/yr)

<table>
<thead>
<tr>
<th>Year</th>
<th>NSW</th>
<th>QLD</th>
<th>VIC</th>
<th>SA</th>
<th>WA</th>
<th>TAS</th>
<th>NT</th>
<th>ACT</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>618</td>
<td>305</td>
<td>518</td>
<td>105</td>
<td>94</td>
<td>24</td>
<td>15</td>
<td>33</td>
<td>1712</td>
</tr>
<tr>
<td>2000</td>
<td>642</td>
<td>331</td>
<td>531</td>
<td>106</td>
<td>100</td>
<td>25</td>
<td>16</td>
<td>36</td>
<td>1787</td>
</tr>
<tr>
<td>2010</td>
<td>685</td>
<td>379</td>
<td>553</td>
<td>109</td>
<td>112</td>
<td>26</td>
<td>18</td>
<td>41</td>
<td>1923</td>
</tr>
<tr>
<td>2020</td>
<td>730</td>
<td>435</td>
<td>576</td>
<td>112</td>
<td>125</td>
<td>27</td>
<td>20</td>
<td>46</td>
<td>2072</td>
</tr>
</tbody>
</table>

*Note:* assumes constant wastewater flow per capita, for each year, within each state.

Unless counteracted by water conservation gains, population growth plus economic growth tends to increase water consumption and wastewater flows, and leads to a demand for new disposal facilities. Figure 6 shows trends in per capita water use in four capital cities since the 1970s. It is noteworthy that per capita use in the Hunter
Region has been virtually static since the mid 1980s, despite well known demand management initiatives, while per capita use from the WA Water Authority scheme has increased in Perth, from the low levels of the early 1980s. These were the two cities with the longest record of active pricing reforms. In the capital cities, the trend of household water consumption has generally been a slow, but perceptible increase in per capita water use. In Sydney the trend in per capita water consumption shown in Figure 6 was 0.6% per year. In Perth it has been approximately 2% per year. If the trend continues it will place additional strain on existing disposal systems. Sewage authority predictions suggest that total wastewater flows into treatment plants may increase by nearly 50% between 1994 and 2020.

![Graph showing per capita water use](image)

**FIGURE 6.** Trends in per capita water use in Melbourne, Sydney, Hunter District, and Perth

11.10.2 *National survey results*

Table 30 summarises the current and future wastewater flows to the year 2020, that are anticipated by wastewater utilities, from the NERS, 1994. Figure 7 shows the wastewater volumes by state for 1994. Table 31 expresses these projections as annual growth rates, while Table 32 provides predicted population growth rates for comparison. Figure 8 shows per capita wastewater flows by state in 1994 from the National Effluent Re-use Survey. It is notable that Western Australia, South Australia and the Northern Territory have lower per capita flows. This is generally due to the comparative level of sewerage provision.
Table 30. Total volumes of wastewater received and anticipated (ML/yr)

<table>
<thead>
<tr>
<th>Year</th>
<th>ACT</th>
<th>NSW</th>
<th>NT</th>
<th>Qld</th>
<th>SA</th>
<th>Tas</th>
<th>Vic</th>
<th>WA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>33000</td>
<td>618338</td>
<td>15030</td>
<td>305000</td>
<td>104726</td>
<td>50300</td>
<td>507173</td>
<td>93812</td>
<td>1727379</td>
</tr>
<tr>
<td>2000</td>
<td>40000</td>
<td>662959</td>
<td>16000</td>
<td>337635</td>
<td>107683</td>
<td>52552</td>
<td>556625</td>
<td>112016</td>
<td>1885470</td>
</tr>
<tr>
<td>2020</td>
<td>50000</td>
<td>823123</td>
<td>20000</td>
<td>472689</td>
<td>112902</td>
<td>60435</td>
<td>664300</td>
<td>198422</td>
<td>2401871</td>
</tr>
</tbody>
</table>


FIGURE 7. Wastewater volume by state (GL) – 1994

Table 31. Expected rate of growth in wastewater flow(%/yr)

<table>
<thead>
<tr>
<th>Years</th>
<th>ACT</th>
<th>NSW</th>
<th>NT</th>
<th>Qld</th>
<th>SA</th>
<th>Tas</th>
<th>Vic</th>
<th>WA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994-2000</td>
<td>3.26</td>
<td>1.17</td>
<td>1.05</td>
<td>1.71</td>
<td>0.47</td>
<td>0.73</td>
<td>1.56</td>
<td>3.00</td>
<td>1.47</td>
</tr>
<tr>
<td>2000-2020</td>
<td>1.12</td>
<td>1.09</td>
<td>1.12</td>
<td>1.70</td>
<td>0.24</td>
<td>0.70</td>
<td>0.89</td>
<td>2.90</td>
<td>1.22</td>
</tr>
</tbody>
</table>


Table 32. Expected population growth rates (%/yr)

<table>
<thead>
<tr>
<th>Years</th>
<th>ACT</th>
<th>NSW</th>
<th>NT</th>
<th>Qld</th>
<th>SA</th>
<th>Tas</th>
<th>Vic</th>
<th>WA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994-2000</td>
<td>1.33</td>
<td>0.64</td>
<td>1.09</td>
<td>1.36</td>
<td>0.26</td>
<td>0.34</td>
<td>0.41</td>
<td>1.12</td>
<td>1.03</td>
</tr>
<tr>
<td>2000-2020</td>
<td>1.32</td>
<td>0.64</td>
<td>1.19</td>
<td>1.37</td>
<td>0.26</td>
<td>0.34</td>
<td>0.41</td>
<td>1.12</td>
<td>0.73</td>
</tr>
</tbody>
</table>

It is evident from Tables 31 and 32 that the utilities generally predict faster growth in wastewater flow than in population (that is increasing per capita wastewater flow). While this is consistent with past trends, it is questionable whether the survey responses have taken full account of the possible impacts of the National Water Reform Agenda, including changes to water pricing regimes and other demand management initiatives that would affect wastewater flow volumes. Against this, it is also not yet proven what effect pricing changes and demand management will have on total consumption, and within that, their effect specifically on the wastewater component.

Sydney Water has demand management targets that would reduce estimated wastewater flow by about 16% by the year 2000. Thus, under Sydney Water’s demand-management scenarios wastewater flow volume would decline. However, the contaminant loads in wastewater would not be reduced. To the extent that wastewater re-use policies are intended to reduce pollution in receiving environments, the proportional re-use target is just as important as the total volume. As the viability of re-use is linked to volumetric demand in particular water markets, a reduction in per capita wastewater flow might actually facilitate contaminant recycling objectives.
Table 33 summarises the individual State and Territory projections of discharges by type. It is seen that the total expected increase in wastewater flow is some 670 GL between 1994 and 2020. Against this, re-use nationally is expected to increase from 18 GL in 1994 to some 64 GL by the year 2020. Thus, wastewater utilities are generally projecting continued increases in discharge to coastal and inland waters.

Table 33. Current and future discharge volumes, 1994 to 2020 (ML/yr)

<table>
<thead>
<tr>
<th>Disposed to:</th>
<th>ACT</th>
<th>NSW</th>
<th>NT</th>
<th>QLD</th>
<th>SA</th>
<th>TAS</th>
<th>VIC</th>
<th>WA</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In 1994</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>30</td>
<td>28198</td>
<td>1250</td>
<td>30660</td>
<td>6819</td>
<td>8219</td>
<td>12790</td>
<td>161938</td>
<td></td>
</tr>
<tr>
<td>Direct re-use</td>
<td>1</td>
<td>8710</td>
<td>0</td>
<td>1220</td>
<td>2881</td>
<td>910</td>
<td>958</td>
<td>3382</td>
<td>18062</td>
</tr>
<tr>
<td>Inland/fresh waters</td>
<td>32969</td>
<td>138293</td>
<td>1100</td>
<td>31810</td>
<td>1548</td>
<td>14390</td>
<td>74071</td>
<td>875</td>
<td>295056</td>
</tr>
<tr>
<td>Coastal waters</td>
<td>0</td>
<td>443137</td>
<td>9090</td>
<td>240320</td>
<td>93478</td>
<td>35000</td>
<td>326580</td>
<td>76765</td>
<td>1224370</td>
</tr>
<tr>
<td>Total</td>
<td>33000</td>
<td>618338</td>
<td>11440</td>
<td>304010</td>
<td>104726</td>
<td>50300</td>
<td>483800</td>
<td>93812</td>
<td>1699426</td>
</tr>
<tr>
<td><strong>By 2000</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>2050</td>
<td>33427</td>
<td>1600</td>
<td>33941</td>
<td>7134</td>
<td>0</td>
<td>99748</td>
<td>16317</td>
<td>194217</td>
</tr>
<tr>
<td>Direct re-use</td>
<td>5</td>
<td>23851</td>
<td>0</td>
<td>1351</td>
<td>2881</td>
<td>955</td>
<td>1345</td>
<td>17046</td>
<td>47434</td>
</tr>
<tr>
<td>Inland/fresh waters</td>
<td>37945</td>
<td>157593</td>
<td>1100</td>
<td>35214</td>
<td>1548</td>
<td>15031</td>
<td>46306</td>
<td>0</td>
<td>294737</td>
</tr>
<tr>
<td>Coastal waters</td>
<td>0</td>
<td>448088</td>
<td>13300</td>
<td>266034</td>
<td>96120</td>
<td>36566</td>
<td>385901</td>
<td>78651</td>
<td>1324660</td>
</tr>
<tr>
<td>Total</td>
<td>40000</td>
<td>662959</td>
<td>16000</td>
<td>336540</td>
<td>107683</td>
<td>52552</td>
<td>533300</td>
<td>112014</td>
<td>1861048</td>
</tr>
<tr>
<td><strong>By 2020</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>2050</td>
<td>46970</td>
<td>2400</td>
<td>47517</td>
<td>7350</td>
<td>0</td>
<td>135302</td>
<td>28903</td>
<td>270492</td>
</tr>
<tr>
<td>Direct re-use</td>
<td>5</td>
<td>29178</td>
<td>0</td>
<td>1891</td>
<td>2881</td>
<td>1000</td>
<td>12905</td>
<td>15838</td>
<td>63791</td>
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<tr>
<td>Inland/fresh waters</td>
<td>47945</td>
<td>234147</td>
<td>1100</td>
<td>49299</td>
<td>1548</td>
<td>17348</td>
<td>30000</td>
<td>0</td>
<td>381329</td>
</tr>
<tr>
<td>Coastal waters</td>
<td>0</td>
<td>512828</td>
<td>11723</td>
<td>372446</td>
<td>101123</td>
<td>42051</td>
<td>460793</td>
<td>153681</td>
<td>1654646</td>
</tr>
<tr>
<td>Total</td>
<td>50000</td>
<td>823123</td>
<td>15223</td>
<td>471153</td>
<td>112902</td>
<td>60435</td>
<td>639000</td>
<td>198422</td>
<td>2370258</td>
</tr>
</tbody>
</table>

Note: Figures for NT, Tas, and country NSW have been estimated by CSIRO. Figures for other States and the ACT have been provided by the relevant wastewater authority through the National Effluent Re-use Survey.

The projections of future direct re-use given in Table 33 should be regarded as minimums, based on confirmed schemes or adopted targets at the State/Territory level. In future it is likely that other utilities will seriously examine re-use options and that the actual outcome will be for more re-use than appears from these water utility projections, especially if the suggestions given in Section 12 are taken up.

11.10.3 Direct re-use markets

Table 34 shows the types of direct re-use currently envisaged, derived from the NERS, 1994. In 1994 just over a half of direct re-use was for on-site use in treatment plants. In future, larger amounts of effluent will be re-used for industry. Third-pipe urban schemes are expected to grow in number and extent, but are not expected to be a significant part of direct re-use until at least the year 2020, when they are expected to account for about 15% of the total. One of the more attractive aspects of the industrial market, as compared to the residential market, is that its water demand is relatively constant throughout the year. It is notable that, currently, no water authority considers
it likely that groundwaters will be recharged by injection using reclaimed effluent, although this is now a common practice in the USA.

**Table 34. Direct re-use (%)**

<table>
<thead>
<tr>
<th>Year/Nature of Re-use</th>
<th>ACTEW</th>
<th>SW</th>
<th>HWC</th>
<th>E&amp;WS</th>
<th>VIC</th>
<th>WAWA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1994</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-site plant purposes</td>
<td>100</td>
<td>93</td>
<td>100</td>
<td>75</td>
<td>36</td>
<td>56</td>
<td>1</td>
</tr>
<tr>
<td>Industrial</td>
<td>7</td>
<td>44</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Third pipe urban</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Agriculture/mariculture</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Ornamental water bodies</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Groundwater recharge</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>25</td>
<td>48</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>Other</td>
<td>56</td>
<td></td>
<td>16</td>
<td>16</td>
<td></td>
<td></td>
<td>16</td>
</tr>
<tr>
<td><strong>TOTAL Re-use (ML/yr)</strong></td>
<td>1</td>
<td>5110</td>
<td>3600</td>
<td>2881</td>
<td>958</td>
<td>6980</td>
<td>19530</td>
</tr>
<tr>
<td><strong>2000</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-site plant purposes</td>
<td>30</td>
<td>39</td>
<td>100</td>
<td>82</td>
<td>20</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td>26</td>
<td>64</td>
<td>53</td>
<td>39</td>
<td></td>
<td></td>
<td>39</td>
</tr>
<tr>
<td>Third pipe urban</td>
<td>5</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Agriculture/mariculture</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Ornamental water bodies</td>
<td>30</td>
<td></td>
<td>2</td>
<td>11</td>
<td></td>
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<tr>
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<tr>
<td>Other</td>
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<td>36</td>
<td>9</td>
<td>8</td>
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<tr>
<td><strong>TOTAL Re-use (ML/yr)</strong></td>
<td>5</td>
<td>18251</td>
<td>5600</td>
<td>2881</td>
<td>1345</td>
<td>24730</td>
<td>52812</td>
</tr>
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<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>On-site plant purposes</td>
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<td>31</td>
<td>100</td>
<td>11</td>
<td>15</td>
<td>20</td>
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<td>Industrial</td>
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<td>10</td>
<td>45</td>
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<td>39</td>
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<td>10</td>
<td>5</td>
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<td>5</td>
</tr>
<tr>
<td><strong>TOTAL Re-use (ML/yr)</strong></td>
<td>6</td>
<td>23178</td>
<td>6000</td>
<td>2881</td>
<td>12905</td>
<td>40020</td>
<td>84990</td>
</tr>
</tbody>
</table>

*Source: National Effluent Re-use Survey, 1994 (this report)*

*Note: ACTEW – Australian Capital Territory Electricity and Water; SW – Sydney Water, NSW; HWC – Hunter Water Corporation, NSW; VIC – Victoria (state); WAWA – Water Authority of Western Australia; EWS – The Department of Engineering and Water Supply, SA.*

It should be noted that several direct re-use schemes which have not yet proceeded to implementation, and others which are possibilities in future, are not included in the direct re-use projections. In Canberra the projections assume status-quo, even though ACTEW is actively evaluating re-use. Perth assumes no future re-use, which is questionable as a long-term assumption given the economics of future water supplies and
long-term environmental factors. The projection for country NSW assumes zero direct re-use in the absence of any firm projections from the Department of Land and Water Conservation. For Queensland the forecasts assume the same percentage distribution of effluent discharges as existed in 1994.

**Urban Residential Market**

A large potential market exists for the provision of urban residential water, since the largest part of urban water demand is in the residential market. Two-thirds of the water used for urban and industrial purposes in Australia is in the residential (or domestic) sector (Department of Primary Industries and Energy, 1987). Since most of the sewage treatment plants in metropolitan areas are surrounded by urban populations and infrastructure, the residential sector must be considered as a prime market for reclaimed water. Australia’s first dual reticulated housing estates for non-potable re-use are under construction in Rouse Hill, Sydney and New Haven, Adelaide. Household level re-use schemes have been trialed by 6 to 12 houses in Canberra; Shoalhaven Heads, Wagga Wagga, NSW (100 houses); Black Point, Northern Territory; Melbourne, Vic; and Palmyra, WA.

Notable exceptions to this occur in Adelaide (Bolivar Treatment Plant) and Melbourne (Werribee and South East Treatment Plants), where the treatment plants are accessible to rural water users.

There are at least three different re-use markets within the urban residential area:

- potable re-use
- non-potable re-use, and
- household greywater re-use.

Each of these may be considered in terms of new developments or retrofit situations.

Firstly if wastewater can be treated to potable standard, it can be used to replace or supplement existing domestic supply. The potential market is large and well understood. As discussed in Section 10, the direct production cost of reclaimed water is generally higher than that for conventional surface or groundwater sources. However, this cost comparison ignores externalities and the difference made to discharge and water system costs. It seems highly likely that some urban water demands could be effectively supplied by reclaimed water, either to potable or non-potable standard.

While no planned re-use of wastewater for potable purposes occurs in Australia at this time, indirect re-use is occurring, often without the knowledge of the community. In a survey by Hamilton and Greenfield (1991) the water supply from the Condamine River in Queensland, was found to contain 8.6% sewage effluent at Dalby and 7.3% sewage effluent at Chinchilla. The highest concentration of effluent in New South Wales was 5% and 2% in the Namoi River at Walgett and Dunedah, respectively. To a lesser extent, contamination occurs in all of the rivers examined, including the Ballone in Queensland; the Darling, Murrumbidgee and Nepean in New South Wales and the Murray and Yarra in Victoria (Hamilton and Greenfield, 1991). Indirect potable re-use occurs in South Australia where treated effluent from Hahndorf via the Onkaparinga...
River enters the Mt Bold Reservoir and in Myponga where treated effluent is discharged into a small creek which flows into the Myponga Water Supply Reservoir (E&WS, 1994b).

Secondly, non-potable treated wastewater can be piped to houses through a dual reticulation system. If the re-use water is to be used for outdoor purposes and toilet flushing, then it could supply more than half the urban residential water use. The market is limited by the fact that existing houses do not have the required dual reticulation systems. The cost of retrofitting is often quoted as a factor against reclamation schemes. Here again, careful cost-benefit analysis of system operations is needed to test whether this is the case. The experience of Altamonte Springs near Orlando, Florida is salutary. A suburb of 45 000 people was retrofitted using trenchless technology, which lowered both costs and public inconvenience during the installation phase. For Altamonte Springs the retrofit was the cheapest option. Assessment of the retrofit market can only be done on a plant-by-plant basis taking account of urban layout, topography, soils, demand, and costs. Sometimes retrofit might be combined with dual reticulation for new areas. Western Melbourne could be a case in point. Nevertheless, the main potential market is in new fringe developments where dual reticulation can be incorporated into infrastructure design and construction.

Country towns are a likely market for re-use especially where existing water supplies are at or near full capacity and the cost of piping water from other places would be excessive (for example, small towns in rural South Australia) (van der Wel and McIntosh, 1995).

Finally greywater can be re-used domestically for non-contact uses. The potential market is large. However without adequate levels of treatment the greywater is probably only acceptable for sub-surface garden irrigation. In this case the capital costs of setting up these schemes may be the major limitation.

Nevertheless, as can be seen from Table 34 utilities are projecting relatively small volumes of reclaimed water for the residential sectors according to the National Effluent Re-use Survey, 1994.

**Industry**

The primary market for re-use water in industry is to supplant the use of scheme water in applications where lower quality water may be used. At present applications of treated wastewater in industry have been prototype applications and the industrial demand for water at different treatment levels is not well known. The industrial market is quite fragmented, with different industries and uses having particular water quality requirements. Poor water quality may lead to problems such as corrosion, staining, scale deposition and foaming. Costs to industry resulting from potential damage to equipment or disruption of production may be high, so the market is sensitive to the quality of water supplied.

The Clean Waterways study estimated that about 50% of the water used by Sydney Water’s 147 largest consumers could be replaced by treated wastewater. Thirteen per cent of Sydney Water supply went to industrial consumers. To date, the major
industrial wastewater re-use schemes in operation include: the Eraring Power Station in the Hunter Region and Australian Steel Mills at Port Kembla, NSW; and Commercial Polymers Pty Ltd, Vic. At Woodman Point, Kwinana, WA, a demonstration project is underway indicating how effluent can be treated for use in industrial cooling towers. A review of current and planned industrial wastewater re-use is under way by Australian Steel Mill Services Pty Ltd (NSW) and Commercial Polymers Pty Ltd (Vic). Feasibility studies have also been undertaken by the Sydney Water Corporation and the Water Authority of Western Australia, to investigate further industrial re-use options. The Sydney Water Board has identified potential projects for the re-use of treated effluent. These included a planned BHP Steel Mills at Rooty Hill, Paper Mills in Western Sydney and other industries around the Port Kembla Steel Works (Sydney Water Board, 1992).

11.10.4 Land disposal markets

Tables 35 to 37 show types of land disposal in 1994 and expected volumes in the years 2000 and 2020, respectively. A national picture is not available due to the lack of data for several states/territories. For the authorities that provided estimates, 83% of land disposal within urban areas in 1994 was to parks and recreational areas, including, in particular, golf courses. For rural areas, the main types of disposal were either to land treatment schemes or through land disposal without any re-use value. A relatively small part of the total (27%) was used for productive purposes including agriculture, forestry, horticulture and irrigated pastures. In future, the proportion of effluent disposed to these uses is expected to increase to 36% of the total in the year 2020.

Irrigation of Urban Landscapes and Recreation Areas

Direct re-use is most widely practised in Australia for irrigation of golf courses and recreational grounds. There is scope for more wide scale re-use for irrigation of parks, gardens and golf courses. In arid areas of Western Australia, Northern Territory and South Australia small country towns have been reusing treated wastewater successfully for up to 50 years on parks, gardens and golf courses.

The market for general urban irrigation depends on the amount of public open space and the level of irrigation required by these spaces. The urban irrigation market is relatively small and, in line with other irrigation schemes, demand is seasonal. In Sydney, for example it is estimated to be approximately 2000 ML/yr, and this compares with Sydney Water’s total wastewater flow of 424 000 ML/yr: less than 0.5%. The market is often also scattered over long distances thus causing distribution costs to be high. However, in greenfield sites the potential exists for urban irrigation to form part of a system including non-potable residential re-use.
**Table 35.** Land discharges by type in 1994 (%)

<table>
<thead>
<tr>
<th>Discharge Outlet</th>
<th>ACT</th>
<th>SW</th>
<th>HWC</th>
<th>SA</th>
<th>VIC</th>
<th>WAWA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TO URBAN ENVIRONMENT:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parks, Recreation areas</td>
<td>40</td>
<td>76</td>
<td>15</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golf courses</td>
<td>60</td>
<td>86</td>
<td>100</td>
<td>12</td>
<td>85</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Market gardens, orchids etc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetlands/environmental flows</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>Groundwater recharge by flooding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Disposal (no re-use value)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Land treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
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<td></td>
<td></td>
<td></td>
<td>14</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL VOLUME (ML/yr)</strong></td>
<td>30</td>
<td>1098</td>
<td>1400</td>
<td>4152</td>
<td>2238</td>
<td>1053</td>
<td>9971</td>
</tr>
</tbody>
</table>

| **TO RURAL ENVIRONMENT:**                 |     |     |     |     |      |      |       |
| Market gardens, orchards etc              |     |     |     |     | 4    | 3    |       |
| Agriculture                               | 94  | 100 | 3   | 6   |      |      |       |
| Forestry                                  | 6   | 8   | 7   |     |      |      |       |
| Irrigated pastures                        |     |     |     |     | 13   | 11   |       |
| Wetlands/environmental flows             |     |     |     |     | 0    | 0    |       |
| Groundwater recharge by flooding          |     |     |     |     | 0    | 0    |       |
| Disposal (no re-use value)                |     |     |     |     | 8    | 100  | 19    |
| Land treatment                            |     |     |     |     | 64   | 54   |       |
| Other                                     |     |     |     |     | 10   | 1    |       |
| **TOTAL VOLUME (ML/yr)**                   | 0   | 0   | 700 | 2667| 79953| 11737| 95057 |

*Source:* National Effluent Re-use Survey, 1994 (this report). *Note:* Abbreviations are defined in Table 34.

**Table 36.** Expected land discharges by type by the year 2000 (%)

<table>
<thead>
<tr>
<th>Discharge Outlet</th>
<th>ACT</th>
<th>SW</th>
<th>HWC</th>
<th>E&amp;WS</th>
<th>VIC</th>
<th>WAWA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TO URBAN ENVIRONMENT:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parks, Recreation areas</td>
<td>89</td>
<td>6</td>
<td>76</td>
<td>26</td>
<td>43</td>
<td></td>
<td></td>
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<tr>
<td>Golf courses</td>
<td>1</td>
<td>86</td>
<td>94</td>
<td>12</td>
<td>74</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Market gardens, orchids etc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetlands/environmental flows</td>
<td></td>
<td>13</td>
<td>4</td>
<td></td>
<td></td>
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<td>Groundwater recharge by flooding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Disposal (no re-use value)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
<td>11</td>
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<td>14</td>
<td></td>
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<td>3</td>
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<tr>
<td><strong>TOTAL VOLUME</strong></td>
<td>2050</td>
<td>1098</td>
<td>1800</td>
<td>4152</td>
<td>2936</td>
<td>1507</td>
<td>13543</td>
</tr>
</tbody>
</table>

| **TO RURAL ENVIRONMENT:**                 |     |     |     |      |      |      |       |
| Market gardens, orchards etc              |     |     |     | 7    | 6    |      |       |
| Agriculture                               | 92  | 100 | 4   | 7    |      |      |       |
| Forestry                                  | 8   | 13  | 17  | 11   |      |      |       |
| Irrigated pastures                        | 100 | 17  | 15  |      |      |      |       |
| Wetlands/environmental flows             |     |     |     |      | 0    | 0    |       |
| Groundwater recharge by flooding          |     |     |     |      | 0    | 0    |       |
| Disposal (no re-use value)                |     |     |     | 5    | 100  | 18   |       |
| Land treatment                            |     |     |     | 53   | 43   |      |       |
| Other                                     |     | 1   | 1   |      |      |      |       |
| **TOTAL VOLUME**                           | 0   | 1643| 1300| 2982 | 96817| 16796| 119538|

*Source:* National Effluent Re-use Survey, 1994 (this report). *Note:* Abbreviations are defined in Table 34.
Table 37. Expected land discharges by type by the year 2020 (%)

<table>
<thead>
<tr>
<th>Discharge outlet</th>
<th>ACT</th>
<th>SW</th>
<th>HWC</th>
<th>E&amp;WS</th>
<th>VIC</th>
<th>WAWA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO URBAN ENVIRONMENT:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parks, Recreation areas</td>
<td>89</td>
<td>15</td>
<td>76</td>
<td>46</td>
<td></td>
<td>40</td>
<td>2050</td>
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<tr>
<td>Golf courses</td>
<td>1</td>
<td>86</td>
<td>85</td>
<td>12</td>
<td>54</td>
<td>33</td>
<td>1098</td>
</tr>
<tr>
<td>Market gardens, orchids etc</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>2700</td>
</tr>
<tr>
<td>Wetlands/environmental flows</td>
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<td></td>
<td></td>
<td>13</td>
<td></td>
<td>3</td>
<td>4152</td>
</tr>
<tr>
<td>Groundwater recharge by flooding</td>
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<td></td>
<td></td>
<td>0</td>
<td>4308</td>
</tr>
<tr>
<td>Disposal (no re-use value)</td>
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<td></td>
<td></td>
<td></td>
<td>100</td>
<td>4000</td>
</tr>
<tr>
<td>Land treatment</td>
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<td>10</td>
<td>14</td>
<td>2</td>
<td>18308</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL VOLUME</td>
<td>2050</td>
<td>1098</td>
<td>2700</td>
<td>4152</td>
<td>4308</td>
<td>4000</td>
<td>18308</td>
</tr>
</tbody>
</table>

TO RURAL ENVIRONMENT:

<table>
<thead>
<tr>
<th>Discharge outlet</th>
<th>ACT</th>
<th>SW</th>
<th>HWC</th>
<th>E&amp;WS</th>
<th>VIC</th>
<th>WAWA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market gardens, orchards etc</td>
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<td></td>
<td></td>
<td></td>
<td>7</td>
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<td>7</td>
</tr>
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<td>Agriculture</td>
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<td>100</td>
<td>4</td>
<td>6</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Forestry</td>
<td>14</td>
<td>13</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Irrigated pastures</td>
<td>100</td>
<td>5</td>
<td>20</td>
<td>16</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Wetlands/environmental flows</td>
<td></td>
<td></td>
<td>20</td>
<td>0</td>
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<td></td>
<td>100</td>
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<tr>
<td>Groundwater recharge by flooding</td>
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<td></td>
<td>27</td>
</tr>
<tr>
<td>Disposal (no re-use value)</td>
<td>1</td>
<td>100</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Land treatment</td>
<td>39</td>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>39</td>
</tr>
<tr>
<td>Other</td>
<td>16</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>TOTAL VOLUME</td>
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<td>2372</td>
<td>3700</td>
<td>3198</td>
<td>130994</td>
<td>44588</td>
<td>184852</td>
</tr>
</tbody>
</table>

Source: National Effluent Re-use Survey, 1994 (this report). Note: Abbreviations are defined in Table 34.

**Agriculture**

Agriculture uses the majority of diverted water in Australia. There is unmet demand for irrigation water in inland areas of Australia. Since treated wastewater is generally suitable for use on irrigated crops, agricultural re-use could potentially consume the entire volume of wastewater produced. However while the potential supply is high, the market is limited by a number of factors.

Most wastewater used for agricultural re-use is irrigated onto pasture crops for fodder production, turf farms, woodlots or onto grazing land for livestock. Health concerns and the seasonal demand for irrigation water are the major barriers for further re-use by agricultural producers. In the Virginia Triangle (Adelaide) vegetable crops that require cooking prior to consumption have been grown using treated wastewater. The CSIRO FILTER Technique which is being explored to grow crops in Griffith, NSW is designed to overcome inter-seasonal variability in irrigation demand by utilising subsurface storage.

There is also a misfit between sources and users. The major sources of wastewater are the large urban areas, which may be very distant from regions suitable for irrigated agriculture. Consequently transport of water to re-use sites may be expensive and in
many cases impractical. Conversely, in country areas, townships are often close to agricultural areas and hence re-use by the agricultural industry is feasible and practical.

Demand for effluent is seasonal, with demand rising in the dry seasons (Read, 1994). As a result it may be necessary to have an alternative disposal system for wet seasons.

Finally, the agricultural market is price sensitive, so the treatment and transport costs of wastewater may make it uneconomic compared to alternative sources of supply. In such cases it may be necessary to attract subsidies or other forms of government assistance before being considered feasible. It should be recognised that alternative sources of supply are more affordable where the agricultural industry has not been made to pay the true price of supply and hence there is a false sense of security that traditional water sources are not costly. If the true costs of supply were charged, farmers might change irrigation practices and manage and harvest runoff from their properties.

Many rural sewage treatment plants discharge into rivers that have downstream uses including irrigated agriculture. Thus there is an indirect re-use. However the re-use system is generally not operating as a market. Consequently, when considering the market for planned agricultural re-use schemes it is important to consider the existing uses that downstream water may be put to.

12. WASTEWATER RE-USE AND THE NATIONAL WATER REFORM AGENDA

12.1 Initiation of Re-use Projects

As outlined in Section 10, there is good reason to suppose that cost-minimising water utilities will choose a system of supply which tends to equalise marginal and average costs across system components. The best examples of this behaviour in the Australian water industry are the mixed surface and groundwater supply schemes in Perth and Newcastle. Water re-use projects typically come into play alongside conventional surface or groundwater-based schemes when the installed system has tracked up the long-run marginal cost curve, including situations where environmental costs have been internalised.

This pattern of resource development agrees with the theory of the firm which says that enterprises will equate the marginal productivity of resource inputs to production. Governments simply need to ensure that water utilities have institutional and financial incentives to become as efficient as possible and are not inefficiently biased in their decisions by externally imposed signals. Thus, attention needs to be placed on the removal of inappropriate institutional impediments and cost distortions which inefficiently bias utilities away from socially optimal choices.

Water industry regulators in each jurisdiction should ensure that inefficient institutional impediments and cost or pricing distortions affecting potential re-use projects are removed.
12.2 Re-use and Contestable Markets

Earlier discussion has demonstrated that water reclamation projects may tap into different points in the urban water cycle. For example:

- by harvesting local stormwaters
- at the point of discharge by water consumers, whether they are households, industries, commercial centres, or other organisations
- by sewer interception
- by upgraded sewage treatment plants; or
- by direct or indirect return of reclaimed water to consumers.

Also, a range of technologies now exists for water reclamation, including:

- package plants from household to local community scale
- standard treatment processes used in municipal treatment plants
- purpose-built wastewater treatment and re-use systems for industry, and
- purpose-designed wetland systems for treatment of surface runoff or effluent

Furthermore, a range of organisations may become suppliers in the re-use market, including:

- water utilities
- individual households or organisations, supplied with equipment and installation skills by a competitive contracting industry
- urban land developers
- local authorities, and
- private industrial and commercial organisations.

It follows that if there is to be contestability in water supply, then restraints on any of these organisations, technologies and points of access to water for re-use purposes need to be minimised within the normal bounds of public interest conditions.

Corporatised water utilities should not be allowed to pre-empt fair competitive water supply activities by other groups. Specifically, the following should be discouraged:

- charging non-users of utility infrastructure (for example: charging sewage rates irrespective of whether a household is connected)
- denying third-party access to wastewater flows for legitimate re-use purposes
- cross-subsidising particular high-cost conventional water supplies, and
- contractual arrangements with related organisations such as suppliers, water retailers, build-own operators or water users, which exclude competitive supply activities involving re-use.

Governments and water industry regulators should promote contestability in water markets by actively supporting requests for access to water infrastructure and water resources, including wastewater, by third parties such as households, industry, commerce, local government universities and the public sector generally, and by permitting such entities to engage in water production including reclamation, subject to the normal public-interest conditions.
12.3 Pricing of Reclaimed Water and its Alternatives

The price of reclaimed water should reflect its system-wide costs. In most situations these will be less than the direct capital and operating costs of treatment upgrades and re-distribution networks, because of cost savings in other parts of the system, which are attributable to the re-use project.

12.4 Pricing of Water Utility Inputs

There should be economic pricing of competitive water sources. Most water utilities are rapidly moving towards, or already have implemented, economic pricing. However, large water consumers often self-extract without paying any economic resource rental or management costs. There are numerous examples of this. In Perth, private bores account for almost 50% of total water use including household, industrial, horticultural, commercial and other uses (Department of Primary Industries and Energy, 1987). There is no resource rental payment for any of this water, not even to cover actual groundwater management costs. In the Hawkesbury-Nepean catchment area industry, agriculture, golf courses and local councils can pump water from the rivers under license which allows unlimited extraction for 5 years for a minimum fee of $113.

Unless efficient prices, which reflect social opportunity costs of supply, are being posted for all sources of water, re-use projects are unlikely to appear attractive to users.

It is clear from Section 10 that, traditionally, water utilities have not had to pay compensation for any external costs that the water/wastewater operation imposes on the rest of society. In its report on the water and wastewater industry the Industry Commission recommended against such charges, on the basis that it was impractical to estimate the magnitude of the costs (Industry Commission, 1994). But these costs would have a significant influence in any benefit-cost comparison of re-use versus conventional water supply schemes.

It is therefore recommended that water industry regulators examine the full range of opportunity costs of raw water diversion, including management costs and externalities, and impose resource rental charges where appropriate. By ignoring external costs there is also the danger of inefficient choices arising because the external costs have been implicitly over-estimated. This can easily happen if a water quality standard for a receiving water is set at a level which imposes higher treatment costs on wastewater utilities than are justified in terms of the environmental damage costs. This explains the large amount of effort in the UK that has recently been put into a quest for agreed methodologies for estimating the benefits of water quality improvement,
following differences of view between the environmental regulator and the economic regulator about the appropriate level of investment in treatment plant upgrades.

It is recommended that a national study of the direct and external costs and benefits of conventional versus re-use water systems be undertaken under the auspices of the Urban Water Research Association of Australia.

All opportunity costs of water supply and wastewater discharge practices, including externalities, should be signalled to water utilities through their input prices.

Water industry regulators should examine the full range of opportunity costs of raw water diversion by industries, agriculture, commerce, local authorities, the public sector and private households, and impose cost recovery and resource rental charges where appropriate.

12.5 Regulation

There are three regulatory structures which are essential for successful wastewater reclamation projects:

- an economic regulator to ensure contestable markets and pricing
- an environmental/water resources regulator to ensure that target quality of receiving waters is set appropriately, and is met by the industry, and
- a quality control regulator to ensure day-to-day operations of reclamation plants are satisfactory.

Most jurisdictions are moving towards new arrangements which provide the first two of these.

However, there is at present insufficient attention in Australia to the provision of continuous quality control regulation in re-use schemes. The provision of guidelines falls short of this requirement. It was apparent from the visits of the project leader to re-use projects in the USA, that quality control data submitted regularly to an external regulator, which might be a State EPA or Public Health Department. The quality control data includes weekly chemistry laboratory reports from treatment plants and exception reports. If any aspect of the treatment plant went out of normal bounds an exception report was required, detailing the aberration and what remedial actions were taken. Provided they complied with this quality control regulation, the operators of reclamation schemes were generally protected from legal action. This arrangement gave social legitimacy to the re-use scheme, rather than its being the initiative of the utility alone.

It is recommended that all jurisdictions undertaking re-use projects create an independent, continuous quality control regulatory institution.
Three regulatory structures are essential for successful wastewater reclamation projects:

- an economic regulator: to ensure contestable markets and pricing
- an environmental/water resources regulator: to ensure that target quality of receiving waters is set appropriately, and is met by the industry, and
- a quality control regulator.

While the first two are generally present in Australian jurisdiction, more attention is needed to the third if there is to be an active water re-use industry.

State and Territory governments should establish independent regulatory jurisdictions governing the operations of re-use projects. These should require weekly plant performance data and exception reports from wastewater agencies, plus some monitoring of the distribution system for reclaimed water.

The NWQMS Draft Guidelines on wastewater re-use should be adopted as the basic standard for wastewater re-use in Australia.

An additional set of Guidelines should be promulgated for artificial injection of urban wastewaters into groundwater aquifers for subsequent re-use, based on research recently conducted on behalf of UWRAA by CSIRO Centre for Groundwater Studies (Dillon and Pavelic, 1995).

In all States and Territories throughout Australia, the approval of both the Health Department and the Department of Environmental Protection should be required before re-use schemes can proceed.

12.6 Public Acceptability

As indicated in Section 9, the community is generally in favour of water conservation, including re-use, but needs assurance specifically about the public health implications. The public does not support the potable re-use option at present. There is still a huge difference between scientific opinion (of the practicality of potable effluent re-use) and public opinion (of effluent as a resource worth drinking). It is generally true that the public regard ‘treated’ water with a great suspicion, while ‘fresh water’ from a ‘natural’ steam is generally accepted. Water utilities and governments should ensure that the public is well informed about re-use schemes and involved in decisions to undertake them.

Communities currently express mixed views on the acceptability of re-use schemes. There is public resistance to current disposal methods, which have been seen as both environmentally damaging and the waste of a potentially valuable resource. Community education and pilot demonstrations of re-use projects should be encouraged. Public education and public involvement programs should include schools programs, visitor programs to treatment facilities, general public information provisions and community involvement in decision making about new re-use schemes.

The community needs assurance about public health implications associated with wastewater re-use. Water utilities and governments should also ensure that the public is well informed about re-use schemes and involved in decisions to undertake them. Treatment schemes should include the necessary precautions to ensure that the potential risk of disease transmission is within acceptable limits.
12.7 Re-use Guidelines

The recent broadening of the Australian National Water Quality management Strategy Guidelines for wastewater re-use is to be commended. The revised Guidelines now approve of a greater range of end-uses for reclaimed water. There is a need to adopt counterpart guidelines for stormwater re-use and specifically in relation to aquifer injection. Dillon and Pavelic (1995) have provided draft guidelines on the quality of stormwater and treated wastewater for injection into aquifers for storage and re-use. There is also a need for ongoing regulatory quality control functions to be provided for all re-use schemes.
PART III:

STORMWATER MANAGEMENT
PART III:
STORMWATER MANAGEMENT

13. OVERVIEW

13.1 Definitions

For the purposes of this report, ‘stormwater’ includes all surface runoff and infiltration within an urban area. It includes both dry-weather flows and flood discharges. It also includes overflows from sanitary sewers or combined sewer overflow systems (CSOs).

Stormwater management is defined as:

- the planning, design and operation of the natural and constructed conveyance system for surface wastewaters, originating in urban areas, which are subject to varying flow rates and stochastic pollutant loads, so as to achieve the multiple objectives of flood control, target water qualities and environmental/ecological enhancement.

Part II of this report has dealt with questions of stormwater re-use in the general context of wastewater re-use. Part III will therefore concentrate on the control of floods and pollution, the naturalisation of urban waterways, and effects on aquatic ecosystems. Some elements of detention and re-use will also be considered, though less from the point of view of water supply.

13.2 Institutional Context

In Australia, as elsewhere, many organisations impinge on the design and operation of the stormwater system. Typically, at a minimum, water resource management departments, water utilities, planning departments, environmental agencies, national regional and local government, and catchment authorities may all be involved. Section 19 discusses institutional structures and possible reforms.

13.3 Stormwater Quantity and Quality

Surface water runoff is enhanced in urban areas by the replacement of relatively porous natural surfaces and water detaining vegetation with impervious roofs, roads, footpaths, car parks, and other buildings and structures. A range of constituents of stormwater exist which may degrade receiving water. These include: excessive nutrients, heavy metals, faecal bacteria, pesticides, non-reactive sediments and turbidity, oils and greases, and litter, such as cans, bottles and plastic bags (Department of Environment and Land Management, 1993).
Although the impact of stormwater discharges on the receiving environment is related to the extent, level, nature and intensity of urban and industrial development in a catchment, the biological quality is highly variable and under the worst conditions, may be similar to raw sewage or worse (Gutteridge, Haskins and Davey, 1981; Clark, 1992). This is particularly so in low rainfall areas. After extended dry periods, for example, the first flush in Adelaide can have similar characteristics to raw sewage (Pugh and McIntosh, 1991).

A comparison between urban stormwater discharges and effluent from common effluent drainage schemes in South Australia, reported by Pugh and McIntosh (1991), is shown in Table 38. It is evident that the pollutants being discharged to receiving waters from both Adelaide and Mount Gambier stormwater are, in many cases, equivalent (and at times higher) in concentration that those recorded for effluent.

Table 38. Quality of effluent and stormwater in South Australia, selected sites

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Bolivar Treatment Plant Effluent*</th>
<th>Common Effluent Disposal Schemes #</th>
<th>Adelaide Stormwater</th>
<th>Mount Gambier Stormwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salinity (TDS) (mg/L)</td>
<td>1400</td>
<td>1253</td>
<td>56–38900</td>
<td>22–120</td>
</tr>
<tr>
<td>Suspended solids (mg/L)</td>
<td>94</td>
<td>78</td>
<td>2–7120</td>
<td>7–1370</td>
</tr>
<tr>
<td>Biochemical oxygen demand (mg/L)</td>
<td>86</td>
<td>61</td>
<td>n.a.</td>
<td>4–110</td>
</tr>
<tr>
<td>Oil and grease (mg/L)</td>
<td>n.a.</td>
<td>n.a.</td>
<td>&lt;68</td>
<td>n.a.</td>
</tr>
<tr>
<td>Bacteria: Faecal Coliforms (organisms/100mL)</td>
<td>2300</td>
<td>1509259</td>
<td>up to 13000</td>
<td>n.a.</td>
</tr>
<tr>
<td>Nutrients:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total phosphorus (mg/L)</td>
<td>7.6</td>
<td>n.a.</td>
<td>&lt;0.005–53</td>
<td>0.058–2.15</td>
</tr>
<tr>
<td>Total nitrogen (mg/L)</td>
<td>18.7</td>
<td>13</td>
<td>&lt;0.01–159</td>
<td>0.2–28.3</td>
</tr>
<tr>
<td>Heavy metals (mg/L):</td>
<td>n.a.</td>
<td>n.a.</td>
<td>&lt;0.001–4.05</td>
<td>&lt;0.1–2.4</td>
</tr>
</tbody>
</table>


* Activated sludge plant

# Average for Clare, Crystal Brook, Cummins, Goolwa, Keith, Lameroo, Mt Barker, Penola, Tailem Bend, Tanunda, Waikerie, Wallaroo (common effluent-disposal schemes based on lagoons).

n.a. = data not available

13.4 Stormwater Systems in Australia and Overseas

Most Australian towns and cities have separate systems for sanitation and storm drainage. Only in a few parts, notably the eastern suburbs of Sydney, are there combined storm and sanitary sewers. However, in most Australian cities the ‘separate’ systems interact in various ways. Given the high variability of rainfall in many Australian regions, both drains and sewers become overloaded following heavy rainfall events when their design capacity is exceeded. Failures in one system may impact the other. For example, a hydraulically inefficient stormwater system may lead to excessive infiltration to sewers following heavy rain. Any overloading of the sewer system, (for example, following failure of a pump station) will spill over into the drainage system (as has happened in the Swan River near Perth).
There is increasing interest in the question of the optimal mix of combined versus separate sewer systems. In some countries, for example Germany, opinion is switching in favour of a mixed approach, as opposed to a completely combined or completely separate system (W.F. Geiger, pers comm). Most urban wastewater systems in the UK and north east USA are combined sewer systems. The main reasons for this are:

- in a combined system under normal flow conditions, all stormwater is directed to a treatment plant
- there are difficulties in preventing cross-connections and controlling illicit discharges in separate systems, and
- rainfall variability is much less in the UK and the north-eastern USA than, for example, in south-eastern Australia. The relatively reduced peak stormwater loadings mean that the problem of overflows from combined sewers into natural drainage channels during wet weather while problematical in places, is generally acceptable

The flood hydrology of Australian cities means that separate systems will remain the norm. Management will continue to address improvements in the storm drainage system, including those aspects which arise from interaction with the sanitary sewer system. Section 16 describes available stormwater management practices.

14. ENVIRONMENTAL IMPACTS OF STORMWATER DISCHARGES

14.1 International Experience

Internationally, there is accumulating evidence of the role of urban non-point source pollution in causing deteriorating water quality in lakes, rivers and estuaries. As cities throughout the western world are very similar in their emissions of water-borne pollutants, it is relevant to consider the experiences of other countries.

While the pollutant characteristics of stormwater runoff are highly variable, the available international data can be summarised as follows:

- Established urban activities, including residential, commercial, and industrial sectors, may contribute a roughly similar amount of suspended sediment per unit area as agriculture.
- Nitrogen and phosphorus loadings from urban activities are typically lower per unit area than those from agriculture, but in some areas can be comparable in magnitude.
- Urban areas yield much higher concentrations of heavy metals and other toxicants than agriculture.

The US EPA publication “Environmental Impacts of Stormwater Discharges” (United States Environmental Protection Agency, 1992) identifies six primary non-point source activities associated with stormwater runoff pollution near urban areas:

1. agriculture
2. silviculture
3. mining
4. construction industry
5. urban activities in general, and
6. atmospheric deposition.

This study also showed that rural non-point sources represent the largest contribution to use impairment of rivers in the USA. However, for lakes and estuaries, the largest contributors to use impairment are reported to be urban non-point and point sources. Furthermore, when considered on a per unit area basis, urban areas, which take up only 2.5% of the USA’s land surface, account for a disproportionately high degree of water quality impairment, namely:

- 18% of impaired river miles
- 34% of impaired lake acres, and
- 62% of impaired estuary square miles.

In the words of the US EPA (United States Environmental Protection Agency, 1992 p. 8):

> This indicates the importance of focussing efforts on the management and control of stormwater discharges from urban areas and associated urban activities (i.e. storm sewers, urban runoff, combined sewers, hydromodification, land disposal, construction, urban growth) since the potential for further urban growth and cumulative impacts from increased stormwater discharges from expanding urban activities is relatively great.

### 14.2 Environmental Impacts of Urban Stormwater Discharges in Australia

A Discussion Paper, published by the Australian Commonwealth Environmental Protection Agency (CEPA, 1993), recognised that the principal issues in stormwater management vary from one place to another, depending on climate, soils and the urban water environment. Nevertheless, the paper noted the following prevalent features in Australia:

- Urban catchments are much more efficient in shedding water from their surfaces than the natural landscapes they have replaced. As a result, flood flows far exceed the capacity of the original waterways. The more frequent flood flows are now conveyed in hydraulically efficient, but often unsightly pipes and channels. More importantly, however, aquatic ecosystems that depend on the original flow characteristics are now threatened.
- In addition, pipes and channels may discharge large quantities of dissolved and solid contaminants into rivers, lakes and the sea. Stormwater runoff has become the main source of pollutants entering many urban waterways, and may also contaminate groundwater.
- Increased loads on stormwater and sewage networks have increased the frequency of overflows, causing cross-contamination in systems that were designed to be separate. This problem is expected to become more prevalent as the infrastructure deteriorates with age, and especially if there is any increase in the frequency of intense rainfall events as a result of climate change.
• While urban stormwater is not generally of high quality, there remain some relatively clean flows, which, with varying degrees of treatment, can be used for a variety of purposes.

The following sections give illustrative information on the impacts of stormwater on aquatic systems in New South Wales, Queensland, South Australia, and Victoria.

14.2.1 New South Wales
The Sydney Water Project (Dowsett et al., 1995), has presented data on the contribution of stormwater to pollution loads in Sydney’s waterways, including Port Jackson, the Upper and Lower St Georges River, Botany Bay foreshore, Cooks River and the Narrabeen, Dee Why, Manly, and Curl Curl Lagoons. Stormwater accounted for the following contributions to total pollutant loads (the figures quoted give the minimum and maximum contributions found across the set of waterways considered; see Dowsett et al., 1995 pp. 59–60):

- faecal coliforms: 8 to 68%
- nitrogen: 40 to 95%
- phosphorus: 45 to 97%.

Thus stormwater is a significant contributor to water pollution in Sydney, and makes an equal or greater contribution to total pollutant loads when compared with sewage treatment plant discharges and sewer overflows together.

In Sydney in wet weather, the entry of large amounts of stormwater to the sewer system can cause overflows. The water enters from illegal connections, drainage, and infiltration through cracks and joints in pipes. Infiltration accounts for about 30% of dry weather sewage flow. Over 3000 relief points have been designed into Sydney’s sewer system. Leakage from sewers into the Port Jackson catchment, particularly Middle Harbour and the Upper Parramatta River, the Cooks River near its entry to Botany Bay and the George’s River create overflow problems in wet weather. Leakage from sewers into surrounding sand beds is also thought to be a problem in the Botany–Randwick area and around the northern lagoons in Sydney.

14.2.2 Queensland
The importance of wastewater and stormwater management to the health of rivers, lakes, estuaries and embayments has been recognised in south east Queensland, leading to the commissioning of the Brisbane River and Moreton Bay Wastewater Management Study. Another study has recently been initiated, as part of planning for south east Queensland to develop a regional approach to water resource and infrastructure management. This study will cover from Noosa Heads to the NSW border. The quality of stormwater runoff has been identified as a critical aspect. The Queensland and Commonwealth governments are studying and developing strategies (such as integrated catchment management) to address the impacts of land-based inputs of pollution to the Great Barrier Reef ecosystem.
14.2.3 South Australia

In Adelaide there has been increasing concern about the impacts of urban stormwater runoff in the Torrens and Pattawolonga catchments. Debris from vegetation is a particular issue in these catchments, along with the other contaminants normally associated with urban runoff.

14.2.4 Victoria

The Melbourne Water/Melbourne Parks and Waterways publication “Backyard to the Bay: Catchment Impacts, the Urban Waterway Challenge”, by Collett et al., (1993) provided information on the relative importance of various kinds of pollution entering Westernport Bay and Port Phillip Bay from point and non-point sources, drawn largely from studies conducted over the period 1979 to 1985 by the Victorian Environmental Protection Authority and Melbourne Water. Key findings were as follows:

- *E.coli* levels in street gutters exceed those of the Yarra River when measured simultaneously. The relationship between rainfall and elevated *E.coli* levels on beaches adjacent to stormwater drains is well established. *E.coli* levels were influenced by sewage overflows in wet weather, sewer collapses, domestic animals (mostly dogs), and septic tanks in some areas.
- Nitrogen loads to the Melbourne bays from urban runoff and atmospheric fallout are significant and increasing.
- Urban runoff contributes the majority of toxicant loads to Melbourne’s bays. A wide variety of toxicants, including heavy metals, is found, mainly in association with sediments. Contamination of sediment increases the costs of disposing of dredge spoil.
- The vast majority (around 95%) of all litter items in receiving waters are from diffuse catchment sources, and particularly high-generation zones such as shopping centres. Two-thirds of this is plastic material, and most of the remainder is paper. Glass and metals are a minor element.
- Higher sediment loads are transported in stormwater than in sanitary sewers. Land disturbance during infrastructure construction is a major source of soil loss to waterways. The dredging and disposal of sediment for navigation and flood control purposes is very costly.
- The study concluded that, given the already well-advanced provision of treatment for sewage, the law of diminishing returns would suggest that efforts to improve the quality of stormwater runoff would be more efficient than further controls on sewage effluents.

Since the “Backyard to the Bay” Study (Collett et al., 1993), the Port Phillip Bay Study has been completed. This has produced more up-to-date information that has confirmed the earlier conclusions. According to Harris et al., (1996), discharges from stormwater in the Port Phillip Bay area (South Australia) have been identified as a major impact on the Bay’s ecosystem. The large but infrequent discharges from urban stormwater are estimated to have a greater adverse affect on the ecosystem, relative to treated sewage effluent in the Bay area. Furthermore, recommendations put forth in the Final Report of the Port Phillip Bay Environmental Study (Harris et al., 1996), emphasise cleaning up urban stormwater as the highest priority.
Throughout the developed world, the objectives of drainage management have been revised over the last decade. Whereas the provision of flood protection was once the sole purpose of drainage management, other objectives now include general pollution abatement, ecological regeneration, and enhancement of environmental amenity for urban dwellers.

As Niemcynowicz (1994 p. 6-1) has stated:

*The fundamental problem of linear flows of matter and energy, i.e. the problem of accumulation, is not properly addressed in present societies. Because water is a general solvent and carrier of residuals, water management is a key issue that cannot be separated from the management of other resources and human activities.*

In addition to the objective of reducing pollution, there is also increasing emphasis on the naturalisation of urban waters and landscapes. As Ellis (1995 p. 19) has stated:

*Principles and guidelines are... [needed]... for the development and implementation of integrated design approaches to achieve sustainable levels of environmental enhancement in urban floodways and corridors.*

*In-channel bio-engineering combined with out-of-channel landscaping offers a range of opportunities for conservation, recreation and amenity as well as providing basic flood and pollution control.*

*In addition, integrated local-scale restoration and remediation is compatible with holistic concepts of wider catchment management, as well as supporting local community objectives of land enhancement.*

Ellis outlined changing government attitudes to stormwater management, as follows:

- The objectives of floodwater control and pollution management are being supplemented with aesthetic, recreational, ecological and economic objectives.
- Strategic principles for sustainable development now include precautionary principle, polluter pays and ecosystem carrying capacity. The internationally-agreed AGENDA 21, *(to which Australia is a signatory: Ed)* provides an action planning basis for strategic and integrated approaches. Consequently, conservation and enhancement of the water environment are now seen as an essential component of the decision-making process in land use change, relying on a collaboration between water managers, catchment planners and land use planners.
- Design approaches require sensitivity to ecological aspects, planning, landscape and local cultural/historical needs, and should be done in the context of master plans describing land use, drainage requirements, flow detention devices, and pollution control.
As recommended by Ellis (1995), principles and guidelines are needed for the development and implementation of integrated design approaches to achieve sustainable levels of environmental enhancement in urban floodways and corridors. Stormwater management design approaches require sensitivity to ecological aspects, planning, landscape design and local cultural/historical needs, and should be done in the context of master plans describing land use, drainage requirements in terms of flow paths, flow detention devices, and pollution control.

Stormwater management should not proceed without satisfying specific water quality objectives, particularly conservation of water as a scarce resource, and its equitable allocation in meeting a range of community needs, without detriment to the environment.

For new urban developments, integrated water cycle management and the related development of watersensitive urban design guidelines, need to replace traditional drainage design principles.

16. STORMWATER MANAGEMENT PRACTICES

16.1 Overview of Practices

There is a large number of management practices which may be applied in any stormwater catchment. These may be conveniently classified according to:

- the stage of the water cycle, for example: at source, (at the point where rain falls); in-channel (either natural or constructed drains), or at the bottom of the system or sink, (whether at a point of discharge to a surface water, or a point of infiltration to groundwater), and
- whether the management practice is structural or not (non-structural practices typically involve individual behaviours, or mandate organisational restraints such as in building codes, licences etc).

The United States Environmental Protection Agency (1992) identifies examples of successful stormwater source control practices. Geiger and Dreiseitl (1995) give a comprehensive review of new methods for managing stormwaters, from a European perspective. Taking account of the papers presented at the Novatech 1995 Conference, the US EPA listing of structural and non-structural controls has been expanded by introducing additional controls, those listed in Table 39.

Multiple stormwater management objectives demand innovation and flexibility on the part of designers. For example, it is important for designers to ‘flood proof’ their pollution source controls, so that the good work done in normal weather conditions is not undone in a flood. A wetland providing sediment collection and biological treatment may be scour out in a flood unless by-pass structures are provided.

The following sections briefly comment on factors influencing the performance of management practices considered individually. Many of the comments in the following sections are attributable to Aitken’s (1995) report to UWRAA entitled Benchmarking and Best Management Practice for Urban Waterway Management, and the

16.2 Structural In-line Controls

These are the standard hydraulic solutions to flow and quality management in drains. As Aitken (1995) points out, the effectiveness of in-line hydraulic controls on water quality can be measured by monitoring flow rates and pollutant inputs and outputs, even though this is not occurring with great frequency.

Table 39. Structural and non-structural source controls

<table>
<thead>
<tr>
<th>Structural</th>
<th>Non-structural</th>
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</thead>
<tbody>
<tr>
<td><strong>Source Controls</strong></td>
<td><strong>Source Controls</strong></td>
</tr>
<tr>
<td>• on-site detention</td>
<td>• zoning</td>
</tr>
<tr>
<td>• in-situ re-use</td>
<td>• subdivision regulations</td>
</tr>
<tr>
<td>• permeable surfaces</td>
<td>• water-sensitive</td>
</tr>
<tr>
<td>• infiltration trenches/swales</td>
<td>design guidelines</td>
</tr>
<tr>
<td>• infiltration basins</td>
<td>• restrictive covenants</td>
</tr>
<tr>
<td>• sand filters</td>
<td>• buffers and setbacks</td>
</tr>
<tr>
<td>• extended detention ponds</td>
<td>• source pollution prevention</td>
</tr>
<tr>
<td>• biological control wetlands</td>
<td>• spill control programs</td>
</tr>
<tr>
<td>• multiple pond systems</td>
<td>• road maintenance programs</td>
</tr>
<tr>
<td>• wetland retrofits</td>
<td>• public education</td>
</tr>
<tr>
<td>• illicit connection controls</td>
<td>• pet control</td>
</tr>
<tr>
<td></td>
<td>• drain labelling</td>
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<tr>
<td></td>
<td>• EIS</td>
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<tr>
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<td>• permitting</td>
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<tr>
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<td>planning models</td>
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<td>• inundation models</td>
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<td>• adaptive management</td>
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<tr>
<td><strong>In-line controls</strong></td>
<td><strong>In-line controls</strong></td>
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<td>• inlet design</td>
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<td>• in-line storages</td>
<td>• in-line storages</td>
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<tr>
<td>• overflow/bypass design</td>
<td>• overflow/bypass design</td>
</tr>
<tr>
<td>• radar/real-time control</td>
<td>• radar/real-time control</td>
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<tr>
<td>• CSO management</td>
<td>• CSO management</td>
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<tr>
<td>• litter booms</td>
<td>• litter booms</td>
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<tr>
<td>• gross pollutant traps</td>
<td>• gross pollutant traps</td>
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<tr>
<td>• sediment traps</td>
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<tr>
<td>• geotextile filters</td>
<td>• geotextile filters</td>
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<tr>
<td>• hydrodynamic separators</td>
<td>• hydrodynamic separators</td>
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<tr>
<td>• oil/grit separators</td>
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<td>• chlorination/dechlorination</td>
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<td>• coagulation/flocculation</td>
<td>• coagulation/flocculation</td>
</tr>
<tr>
<td>• lamellar decantation</td>
<td>• lamellar decantation</td>
</tr>
</tbody>
</table>
16.2.1 Flow controls
These are the standard hydraulic structures used in flood control, including channels with given roughness characteristics, gates, weirs, and surface storages. Recently, increased attention has been given to flow control at source (see Section 16.3).

More recent developments in the operation of installed sewerage and drainage systems for large cities in Europe and the USA have been concentrating on real-time weather forecasting using radar systems, linked to optimal use of the storage available within the drainage system. This is particularly relevant for combined sewer systems, but also has potential for separate drainage systems in cities such as Melbourne, Sydney and Brisbane. Jorgensen et al., (1995) have suggested that real-time optimal control can reduce event CSO volumes by up to 25%.

16.2.2 Litter and sediment traps
Many organisations use litter and sediment traps in their drainage systems.

Entry gates to constructed drains below streets can be either side-entry or horizontal grate type. Side-entry is often favoured in Australian cities because of rainfall intensity. There is increasing tendency to replace traditional side-entry systems with either grates or modified side-entry designs which perform a limited amount of trapping of litter and debris.

As Aitken (1995) complains, the literature is simply bereft of litter trap designs of proven effectiveness. Often, simple fencing systems are used. They are invariably unsightly, and require a high level of maintenance. Trash racks come in various designs from simple screening bars, which are difficult to maintain, to more sophisticated designs which are self-cleaning to some degree. These devices are often used in conjunction with gross pollutant traps.

16.2.3 Gross pollutant traps
Gross pollutant traps (GPTs) are designed to trap litter, debris, and coarse sediments in drains. They are often quite large concrete structures. They sometimes incorporate a weir, and upstream of this swales may be provided along the stream bank to accommodate flows and impounded water during heavy rainfall events. These structures are used in Brisbane, Sydney, and Melbourne; and extensively in Canberra, which has 10 large and 26 smaller installations.

As with all litter-removing structures, GPTs require regular maintenance, and good initial design. They also require significant financial outlay and land areas.

16.2.4 Oil and sediment separators: vortex, swirl and dynamic separators
These facilities exploit the separating potential of circular flow, often incorporating skimming devices. The separated materials are either stored and collected, or delivered to a nearby sanitary sewer. Oil and sediment separators are often sited on drains near car parks and other points of high traffic density in commercial centres.
16.3 Structural Source Controls

16.3.1 Water-sensitive urban design

The concept of water sensitive urban design (WSUD), which is considerably wider than that of ‘drainage’, refers to the conservative use of both stormwater and wastewater through integrative approaches. An overview of current best management practices for designing subdivisions to save and manage water is given in Phillips and Goffman (1993), based on papers and techniques presented at the third Better Cities Technical seminar held in Adelaide in 1992. Individual technical approaches which can be used within WSUD are discussed in the following sections. A few examples of the integrated nature of WSUD are given below.

Moran (1993) developed a set of “Water Sensitive Urban (Residential) Design Guidelines” for application in Western Australian conditions. These have subsequently been applied in a number of research and planning studies. Experiments in Adelaide and Perth have been based on the principles of water-sensitive urban design. These approaches address flooding, water quality, re-use and environmental issues.

A recent example of integrated detention strategies is the “Stormwater Management Strategy and Plans” for the Byford and Mundijong urban development areas south-east of Perth (Evangelisti and Associates and Landvision, 1994). This area suffers from water-ponding on clay soils following winter rains. The development of an urban plan incorporating multi-purpose water management corridors, distributed detention basins, artificial wetlands, recreational lakes and channels, and protected areas of natural vegetation promises to turn a planning constraint into an opportunity.

Argue (1995) has suggested that the following performance standards are achievable for stormwater source management practices in Adelaide:

- stormwater runoff peak flows to be reduced following urban redevelopment
- all storm runoff to be retained within 300m of its point of origin in the catchment in new urban developments
- all pollution to be retained within 300m of its point of origin in a catchment, and
- stormwater to be collected or retained close to its point of origin and used for non-potable applications such as catchment greening, open space irrigation, industrial use (using surface or sub-surface storage).

Much has been said about the scope for enhancing environmental amenity while improving on-site detention by building water features into the built environment. There are many fine examples in Europe and north America. However, there are a number of reasons why this approach is less suitable in Australia. Firstly, rainfall variability in Australia is much greater, and so the provision of a permanently flowing water feature based on frequent, moderate rainfall as in Europe and north-east America is not possible. Secondly, in many Australian regions the ‘proper’ place for water is below the ground: urban landscape features may be better achieved in an Australian context by infiltration which sustains attractive and interesting vegetation communities within our cities.
16.3.2 On-site detention

On-site detention may make only a moderate contribution to flood control objectives. This is particularly true for the larger, less frequent floods.

O’Loughlin et al., (1995) describes experiences with on-site detention systems in Sydney and Wollongong. He reported that on-site detention systems do retard runoff, and their effects can be reasonably gauged by computer simulation models when these are based on accurate descriptions of the drainage system. But a major challenge for stormwater programs utilising such source controls is to ensure that designs take account of ongoing maintenance and performance monitoring requirements. O’Loughlin et al., (1995) reported design or construction faults with about 90% of the 3500 on-site systems in the Sydney–Wollongong region. Many were reported to have stopped functioning due to poor maintenance, construction or design faults.

The poor performance of many installations of the last 30 years can largely be explained by the inadequacy of the supporting technology and the lack of standardised design and installation skills. On-site detention remains a key element of source control and is being improved continuously. Nicholas (1995) has summarised a range of new techniques. These include:

- high early detention: a method of maximising outflow at the onset of storms in order to conserve storage capacity
- screened outlets: to closely control flow rate and capture litter, debris, and sediment
- frequency-staged storage: this employs all available storage opportunities such as lawns and gardens, depressions in public open spaces, and open and covered pavements such as car parks, but in a staged fashion, so that each storage comes into operation only when the preceding one is full
- tailwater compensation: a method of controlling discharge when the bed of a storage lies below the water surface in the receiving drain
- pump discharge regulation: a method for controlling pumpage from basement tanks
- quality enhancement through separation and treatment of first flushes.

As is clear from the above, a critical component of on-site detention systems is control of the rate of release of impounded waters into the drainage system. Higgins (1995) describes an Australian device which permits the maximum allowable discharge to be quickly reached, reducing the storage required for the design storm, and producing relatively constant discharge over a range of operating depths.

At present over 90% of local authorities in Sydney use on-site detention in their stormwater management strategy, requiring its use in virtually all new development and for much redevelopment. Many systems are based on dry surface basins or concealed storage tanks. As Nicholas (1995) points out, conveyance systems which surcharge every two or three years are quite common, but despite the flood risk, local authorities are unwilling or unable to expand the drainage infrastructure. Lacking the funds for widespread enlargement of the drainage network, they encourage landholders to take up some of the responsibility, and to meet their legal obligation under
planning laws to consider downstream stormwater impacts when planning developments.

16.3.3 Constructed wetlands and pollution control ponds

Wetland and pollution control ponds are used internationally to biologically treat stormwater (Aitken, 1995). These are small lakes with fringing vegetation, sometimes designed with a geometry that encourages deposition of sediments. Their intention is to retain runoff long enough to allow aquatic plants to take up nutrients and provide a filtering medium, sunlight to kill bacteria, and sediments to settle. Wetlands are distinguished from ponds by having a larger vegetated area, a greater variety of water depths, and more complex structures. The term can mean any surface which is periodically saturated with water. The effectiveness of these source controls is difficult to accurately determine from studies carried out to date, though research is continuing, especially within the Cooperative Research Centre for Freshwater Ecology, at Canberra University and Albury-Wodonga.

16.3.4 Infiltration drainage, including permeable surfaces

Replacement of porous natural surfaces with impermeable artificial ones is a principal reason for the existence of urban stormwater problems (O’Loughlin et al., 1992). Permeable pavements can restore some of that lost infiltration capacity and also retain pollutants that would otherwise be washed away.

Argue (1995) reported detailed evaluations in Adelaide of rainwater tanks, micro gross pollutant traps, houses with leaky well, houses with gravel-filled trench, roof runoff from a cluster development with bore, single-sloping road carriageway with swale and gravel-filled infiltration trench, and a mixed development including a park with a bore.

In Japan, Germany, Sweden, and France permeable pavements are being used extensively for carparks, footpaths, and occasionally roads (Aitken, 1995). Considerable reductions in washoff of lead, suspended solids and COD levels have been achieved in carparks. These structures are reported to be cost effective, because other drainage infrastructure has been either eliminated or down-sized (Balades and Chantre, 1990). Nevertheless the use of porous pavements does imply increased operating costs as the structure needs to be cleaned and sometimes replaced (every 5 to 10 years in some instances). If soils are not conducive to percolation, or groundwater must be protected, permeable pavements can employ sub-surface drains or lamellar decantation to discharge to a nearby surface drain. There is still some gain in pollution control and runoff peakedness (Aitken, 1995).

Another strategy is for urban planners to try to minimise the area of impermeable surfaces in new developments. In Denver, USA, this practice extends to fitting grassed swales to collect and detain the first 13mm of runoff. Canberra and Brisbane make extensive use of swales.

Sand filters are used in many places, including the USA, France and eastern Europe, to treat runoff from roads, commercial and residential areas. They are considered effective in removal of sediments and attached pollutants. They may often incorporate cascade inlets and a two-stage storage, one a permanent pool for sediment settling,
and the other for filtration through the sand medium with an outflow through a sub-
surface drain. In Perth, the ubiquitous sandy soils allow road runoff to be directed
towards numerous local infiltration basins, or sumps. These are no more than fenced,
medium-sized excavations, and their effectiveness in filtering contaminants, and so
protecting surficial groundwaters is not known. Generally, sand filters are difficult to
design, construct and maintain. In particular, the accumulated filtrate may be highly
contaminated, and requires regular removal.

16.4 Non-structural Source Controls

16.4.1 Construction, other site-based controls and activity controls
The use of controls on sediment export from construction sites is common. Recom-
mended controls include diversion channels and contour drains, sediment retention
ponds, silt fences and hay bales, and vegetated buffer strips. Guidelines for the use of
these tools are generally available. Aitken (1995) observes however, that enforcement
is often lacking in Australian cities.

While construction sites are responsible for a high proportion of sediment fluxes in
urban areas, stormwater management programs addressing toxic materials need also to
take account of industrial facilities for leaks and spillages, materials stockpiles and
waste disposal sites, such as landfills and car wrecking yards. In the USA under the
National Pollution Discharge Elimination Scheme, individual sites are licensed. Most
Australian States and Territories have environmental approval procedures for individ-
ual activities. However, there are few studies which provide an estimate of the collect-
ive contribution of such sites to urban water pollution. Consequently, there is no way
of determining whether the present environmental conditions being applied in granting
development approvals or periodic license renewals are appropriate.

Roads are a significant source of waterway contaminants, and some progress may be
achievable through traffic management, as is done as a part of the stormwater manage-
ment programs in Santa Clara Valley and Alameda County in the USA. Urban plan-
ners can also contribute by designing road systems which are distanced from sensitive
receiving waters, or which have appropriate in-line collection and treatment systems.

16.4.2 Product controls
Some commonly-used manufactured products emit material that contaminates urban
runoff. A few examples are given here. Motor vehicles are a significant source of
waterway pollutants. The copper content of brake pads has been identified as a major
source of contamination of stormwater. In the case of household detergents, SCARM
is currently considering new regulations for phosphorus content, while NSW may also
move independently to implement new regulations. Many products used in the build-
ing industry shed metals and/or chemical compounds. National coordination is desir-
able, as production facilities for these products invariably serve a national market.
The general promotion of recycling is also an important part of product controls, and particularly the re-cycling of packaging materials which constitute a significant portion of litter in stormwater.

16.5 Combined Sewer Overflows

Overflows from combined sewers during storm events result in the discharge of untreated sanitary sewage to receiving waters. This may also contain pre-treated industrial wastewaters and untreated stormwater (United States Environmental Protection Agency, 1993). In many cases, the discharges from combined sewer overflows (CSOs) generally have an adverse effect on receiving water quality. A range of control technologies are available for reducing pollutant discharges from CSOs. These are presented below.

CSO control concepts and design details are influenced by the specific performance goal that is applied. Control goals are usually governed by receiving-water-quality-based and/or technology-based requirements. Examples of commonly encountered performance goals include:

- percent capture: where a specified percentage of flow is captured and/or treated
- overflow frequency: where the number of untreated CSOs per year is reduced to a specified number
- treatment level: specifying the pollutant removal efficiency of the CSO controls
- first flush: providing capture and/or treatment of some portion of a total overflow, determined to contain a major fraction of the pollutant load, and
- cost effectiveness: basing the size of a control unit on cost effectiveness (United States Environmental Protection Agency, 1993).

In general, control practices may be divided into one of three categories:

- practices that restrict the rate and/or volume of stormwater runoff that enters the combined sewer system
- pollution prevention practices that reduce the quantity of pollutants that enter the system, and
- operation and maintenance practices for the combined sewer system that improves its ability to contain wet weather flows and deliver them to treatment works (United States Environmental Protection Agency, 1993).

The characteristics of combined sewer systems are site-specific, and often a number of possible alternatives exist for a given community. A range of control technologies are available to manage sewer overflows. The six most commonly cited (US Environmental Protection Agency, 1993), are:

1. in-system controls/in-line storage
2. off-line near-surface storage/sedimentation
3. deep tunnel storage
4. coarse screening
5. swirl/vortex technologies, and
6. disinfection.

These are discussed below.

### 16.5.1 In-system controls/In-line storage

By utilising the available storage and conveyance capacity of existing collection systems and the available treatment capacity at publicly owned treatment works, in-system controls/in-line storage provide a more readily implementable and cost-effective approach to achieving immediate reductions in CSO volumes (United States Environmental Protection Agency, 1993). In-system controls/in-line storage reduce overflow volumes by allowing a larger fraction of the total flow from a storm event to be conveyed to the treatment works for treatment.

In-system technologies which contribute to maximising in-line storage, maximising flows to treatment works and reducing overflow volumes include: collection system inspection and maintenance; tidegate maintenance and repair; reduction of surface inflow; adjustment of regulator settings; enlargement of undersized pipes to eliminate flow restrictions; removal of obstructions to flow (example, sediments); polymer injection to reduce pipe friction; in-system flow diversions through existing system interconnections; adjustment and/or upgrade of pumping station operations; partial separation of storm drain connections from combined sewers; and infiltration removal (United States Environmental Protection Agency, 1993).

### 16.5.2 Off-line near-surface storage/sedimentation

Off-line, near-surface storage/sedimentation facilities consist of tanks that store and/or treat combined sewer flows that have been diverted from combined trunk sewers and interceptors. These facilities are constructed at near-surface depths that allow the use of traditional open-cut excavation techniques (as opposed to deep tunnel storage). These near-surface storage treatment facilities provide storage up to the volume of the tanks, as well as sedimentation treatment for flows that pass through the facilities in excess of the tank volume. Sizing criteria for the storage tanks vary, depending upon the goal of the CSO control facility. However, coarse screening, floatables control, and disinfection are commonly provided (United States Environmental Protection Agency, 1993).

### 16.5.3 Deep tunnel storage

Deep tunnel storage may be used as an alternative to off-line, near-surface storage/sedimentation facilities in areas where space constraints and potential construction impacts exist. A major advantage of deep tunnel storage is that relatively large volumes can be stored and conveyed with little disturbance to existing surface features. Deep tunnel construction may also avoid some of the issues arising from the use of open spaces in congested urban areas, and minimise the disruptions associated with
the extensive open-cut excavation associated with near-surface facilities (United States Environmental Protection Agency, 1993).

Typical deep tunnel storage systems include: regulators (to divert and control storm flows into the tunnel system); consolidated conduits (to convey flows from regulators to the tunnel system); coarse screening (to remove large debris and protect downstream pumps); vertical dropshafts (to deliver flow to the tunnel and dissipate energy); air separation chambers (to allow release of air entrained in the dropshafts); the tunnel (sized to store and convey flows from a given design consideration); access shafts (for maintenance personnel and equipment); vent shafts (for balancing air pressure); a de-watering system (to pump volume stored in the tunnel to the treatment works once conveyance system and treatment capacity is restored; and odour control systems at certain venting locations (United States Environmental Protection Agency, 1993).

16.5.4 Coarse screening

Coarse screening technologies are designed to protect downstream equipment by providing coarse solids removal, as well as a degree of floatables removal. Coarse screening equipment consists of vertical or inclined steel bars spaced evenly across a channel, and is traditionally located at the headworks of the treatment works. Examples of bar screens used at CSO control facilities include trash racks and both manually and mechanically cleaned screens (United States Environmental Protection Agency, 1993).

16.5.5 Swirl/vortex technologies

Swirl concentrators and vortex separators are compact flow-throttling and solids-separation devices that regulate flow and remove solids and floatables in combined flows. The operation of swirl/vortex technologies comprises the following general mechanisms:

- flow entering the unit is directed around the perimeter of a cylindrical shell, creating a swirling, vortex flow pattern
- the swirling action throttles the influent flow, causing solids to be concentrated at the bottom of the unit
- throttled underflow containing the concentrated solids passes out through a foul sewer outlet in the bottom of the unit
- clarified supernatant passes through the top of the unit.
- underflow is discharged to the downstream interceptor for treatment at the treatment works
- baffle arrangements capture floatables in the supernatant
- floatables are carried out in the underflow when the unit drains, once storm flows subside (US Environmental Protection Agency, 1993).

16.5.6 Disinfection

Disinfection destroys or inactivates microorganisms in overflows, and its effectiveness is measured in terms of reduction in bacterial concentration. This is achieved through
contact with a range of disinfection technologies (including gaseous chlorine, liquid sodium hypochlorite, chlorine dioxide, ultraviolet radiation and ozone). Liquid hypochlorite is the most commonly selected means for disinfecting CSOs (United States Environmental Protection Agency, 1993).

16.5.7 Other control technologies

Other control technologies that have been applied to CSOs include dissolved air flotation, fine screens and microstrainers, dual-media high rate filtration, and biological treatment. These are discussed in more detail in United States Environmental Protection Agency (1993).

A range of control techniques may also be used to supplement the application of control technologies at a CSO discharge location. Implementing an appropriate technology (or combination of techniques) can enhance performance of the control technology applied and, in some cases, reduce design size and cost while still maintaining targeted performance objectives (US Environmental Protection Agency, 1993).

16.6 Summary: Management Approaches

The different management practices discussed above contribute variously to the achievement of stormwater management objectives. The combination which best suits a particular catchment will be unique to it. It is a matter for stormwater managers to select an appropriate mix of achievable objectives in particular catchments, and the contribution of source controls will vary in each case.

New technical developments are changing the methods available for urban stormwater management. For example:

- real-time control systems are being linked with enhanced modelling capability for storage optimisation within the drainage system during flood events
- source controls: new water-sensitive principles for urban planning and landscaping and innovative hydrologic/hydraulic structures are being promulgated
- research is increasing our knowledge of appropriate design principles and physical/chemical/biological dynamics of natural and constructed wetland systems
- there is a widening range of pollutant/sediment control devices and flow control devices
- increasing attention is being paid to the physical, biological and chemical treatment of stormwater
- a wider range of devices for monitoring, including remote-control, in-situ sampling for flow and quality is becoming available, and
- stormwater models are now capable of predicting the behaviour of the drainage system to a high level of accuracy.
A wider set of stormwater management practices needs to be applied including ‘at source’, in-channel, at sink, structural and non-structural methods. These should aim at satisfying all management objectives, and overcoming existing problems of insufficient capital and operational expenditure, under-performance due to deterioration, technical implementation, public commitment and institutional structures. These generally require action by numerous agents in society, as well as drainage utilities (Geiger and Dreiseitl, 1995).

Technical developments that encourage innovation and make multi-objective management of stormwater systems easier in the future, should be encouraged. The potential for a mixture of combined (sanitary and storm sewers) rather than the separate storm drainage and sewer systems which currently exists in Australia should be evaluated.

It is important to keep in touch with the work being undertaken by our international neighbours. Overseas studies on the cumulative impacts from increased stormwater discharges, indicates the importance of focussing efforts on the management and control of stormwater discharges from growing urban areas and associated increased urban activities (i.e. storm sewers, urban runoff, combined sewers, hydromodification, land disposal, construction, urban growth, etc).

Stormwater managers must keep abreast of any advancements in technology and research (including real-time control systems, source controls, research in design principles, pollutant/sediment control devices, physical, biological and chemical treatments, monitoring and models) for managing urban stormwater.

A major challenge for stormwater programs utilising such source controls is to ensure that designs take account of ongoing maintenance and performance monitoring requirements.

17. PUBLIC INVOLVEMENT IN STORMWATER MANAGEMENT

17.1 International Experience

From visits to selected countries (Germany, UK and USA), it was evident that there is general agreement that effective public education was an important element of best management practice. Public involvement is seen as an essential input in the development and implementation of stormwater programs. There are, however, differences in the level of commitment, particularly on the side of public involvement, with some agencies emphasising the education aspect almost exclusively.

There has been growing awareness in the UK of the need for public involvement in controlling sewage constituents, with emphasis on the need to ‘bag and bin’ (not flush). The National River Authority has been keen to develop public involvement within its catchment planning process. From comments at a public meeting it was apparent, however, that some of the public involvement process was being captured by a few vested interests. Again, from an Australian perspective, the emphasis in the USA seems to be on public information rather than involvement in plan formulation and implementation. For example, there did not seem to be any procedure for gaining public comment and feedback on stormwater management plans.
17.2 CSIRO Study

As the first stage of a study which aims to take a national approach to community catchment management of stormwater, a door-to-door survey was conducted in Brisbane, Sydney, Melbourne, and Perth (Nancarrow et al., 1995). A questionnaire was developed to examine the following aspects:

- environmental values for waterways
- knowledge and awareness of stormwater issues
- responsibility for stormwater management
- willingness to pay for stormwater pollution abatement
- potential community action, and
- attitudes.

Briefly, the results of the survey indicated the following:

- The water quality of urban rivers does not meet the community’s environmental values, but in general the community is satisfied with the current level of service in flood control and other aspects of quantity management.
- Knowledge and awareness of stormwater issues are variable across the cities, but there is a clear need for further educational efforts.
- While accepting that both the community and polluters must play a role in future management of stormwaters, many in the community claim to be doing a lot already to help control stormwater pollution (see Table 40); they see stormwater management as providing a public good, and look to public agencies for leadership technical expertise and resourcing.
- There is positive willingness to pay for stormwater quality improvement. Mean willingness to pay across all cities was $54 per year per household. The mean willingness to pay was lowest in Melbourne ($32) and highest in Sydney ($82), with Perth and Brisbane being quite close to the overall average. In policy terms, however, it is also clear from the survey that there is a significant proportion of people who are not prepared to pay for improvements in waterway quality, even if these were perceived to be desirable. These people sought some redistribution of public expenditure from tax revenues, or more efficient expenditure on drainage as the means for further improvement.
- With respect to potential community action, respondents reported that they were already doing many actions which assist with quality management of stormwater.
- Attitudinal scores reflecting personal motivation/lethargy, sense of moral and social responsibility, and familiarity with the problem were the major predictor of potential community action, rather than knowledge of technical facts or perception of personal benefits (for example in personal recreational opportunities).

17.2.1 Individual behaviours

There is a range of individual behaviours which are thought to contribute to stormwater pollution problems. The CSIRO survey (Nancarrow et al., 1995) measured conformity with desirable behaviours, and found that there is indeed already a high compliance rate in most surveyed cities. This suggests that the scope for further
improvement, while positive, may be limited, and that those specific behaviours where compliance is currently low might be targeted by education campaigns.

Pet droppings are a major source of pathogens in urban drainage systems. Collett et al., (1993), estimated that Melbourne’s dog population (estimated to be approximately 300,000) deposits some 90 tonnes of faeces every day, and that a high proportion of this enters drainage systems. Aitken (1995) reports that ‘stoop and scoop’ laws are enforced in many cities internationally: New York, Stockholm, and Toronto are three examples. Other areas have pet zoning regulations. For example, local byelaws have established ‘no-pet’ zones on Perth beaches. Compliance is the key to the success of pet control policies, and this may be achieved by both enforcement and community education/cooperation.

Drain labelling is a means of increasing public awareness of stormwater systems. Community stormwater groups may take on the drain labelling program as a specific task. The dumping of paints, oils, solvents and garden cuttings into drainage systems are particular target activities that might be modified by increased awareness.

It is clear, however, that there are many sources of stormwater pollution which are not addressed by the list of behaviours in Table 40. This underlines the point that community involvement must be accompanied by stormwater management and planning, plus appropriate action and expenditure by public agencies.

### Table 40. Reported stormwater-friendly behaviours in selected Australian cities

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Respondents (%) claiming that they already do listed activity (unweighted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pick up litter from verge outside home</td>
<td>82</td>
</tr>
<tr>
<td>2. Pick up litter from gutter outside home</td>
<td>73</td>
</tr>
<tr>
<td>3. Sweep leaves/dirt from gutter outside home</td>
<td>57</td>
</tr>
<tr>
<td>4. Sweep and not hose paved/concrete areas</td>
<td>71</td>
</tr>
<tr>
<td>5. Wash car on a grassed area</td>
<td>50</td>
</tr>
<tr>
<td>6. Divert roof runoff to garden</td>
<td>22 (57% in Perth)</td>
</tr>
<tr>
<td>7. Install a rainwater tank</td>
<td>3 (9% in Perth)</td>
</tr>
<tr>
<td>8. Remove paved/concrete areas from yard</td>
<td>13</td>
</tr>
<tr>
<td>9. Reduced fertiliser use on lawns/gardens</td>
<td>62 (83% in Perth, 47% in Melbourne)</td>
</tr>
<tr>
<td>10. Pick up animal faeces from verge</td>
<td>43</td>
</tr>
<tr>
<td>11. Take plastic bag and trowel when walking dog</td>
<td>29</td>
</tr>
<tr>
<td>12. Ensure no oil leaks from car</td>
<td>74</td>
</tr>
<tr>
<td>13. Don’t put anything down stormwater grates</td>
<td>91</td>
</tr>
<tr>
<td>14. Join a community stormwater action group</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Nancarrow et al., 1995

### 17.2.2 Evaluation of public involvement

There are serious problems in establishing the performance of behaviour-based source controls. Camp et al., (1992) have suggested some qualitative methods, including:

- measuring the volume of material removed by street sweeping
- undertaking questionnaire surveys to assess public awareness as a function of educational efforts, and
estimating participation rates in recycling and chemical collection programs.

As Aitken (1995) suggests, implementation and monitoring in urban catchments over extended periods seems the most accurate and rigorous means of evaluating performance. Stage 2 of the stormwater study currently being performed by CSIRO is evaluating the performance of a number of community stormwater catchment groups in a controlled experimental situation.

Public education and public involvement are important elements of any stormwater management program, and should be encouraged. The total catchment management movement so evident in rural Australia needs adaptation if it is to be successful in urban areas. There needs to be better general understanding of how the behaviour of individuals can really help to address stormwater objectives, particularly in the area of a number of gross pollutants. Individual initiative needs to be accompanied by clearer definitions of institutional roles, required public investment, technical advice and environmental policies that deal with systemic inadequacies.

Although public information is an important component for raising community awareness, based on international experiences, more efforts should be devoted to allowing the community to provide public comment and feedback on stormwater management practices.

Compliance should be recognised as the key to the success of various stormwater control policies (such as pet control), and this may be achieved by both strict enforcement and community education/cooperation.

Drain labelling is a means of increasing public awareness of stormwater systems. Community stormwater groups may take on the drain labelling program as a specific task. The dumping of paints, oils, solvents and garden cuttings into drainage systems are particular target activities that might be modified by increased awareness.

18. ECONOMICS OF STORMWATER MANAGEMENT

The aims in this section are to provide an overview of stormwater management from an economic perspective, and to provide some Australian and overseas examples of the costs of alternative stormwater management programs.

18.1 Magnitude of Stormwater Pollution Abatement Costs

The cost of stormwater management programs targeting critical environments may be very large. Thus decisions about the appropriate scale and content of stormwater management programs can only be properly resolved through some judgement about whether the required abatement expenditures are justified in economic terms. The stormwater pollution abatement cost curve rises sharply as the stormwater management program is scaled up for dealing with pollutants that can only be addressed by costly technical means.

18.1.1 USA Study

In the USA, drainage engineers are questioning the costs of the NPDES. Montgomery Consulting Engineers (1992) has estimated nationwide USA costs for various levels of
pollutant control implementation. The eight categories of stormwater pollution control considered were:

- institutional source controls: no littering ordinance, ‘pooper scooper’ ordinance, chemical use ordinance, recycling programs, public education programs, vacant lot clean-up ordinance, spill prevention ordinance and programs
- non-structural source controls: prevent illicit discharges, increase street sweeping, cleaning program for storm drains
- minor structural source control: diversion channels, grass swales, channel upgrades to reduce erosion, revegetation
- discharge elimination: recharge areas, porous pavement
- floatables and oil removal: parking lot oil/grease separators, parking lot and roof runoff storage and separators
- solids removal: detention basins, primary clarifiers, swirl concentrators, screens and wetlands
- micro-organism removal: detention basins plus chlorination/dechlorination; swirl concentrators plus chlorination/dechlorination, and
- metals removal: detention basins and wetlands, primary clarifiers and lime precipitation.

Consulting Engineers Montgomery (1992) presented national cost estimates for the USA for five levels of treatment, shown in Table 40 below. Nine climatic zones were used, and estimated unit costs for each BMP were applied to the acreage, precipitation, and stormwater volumes values for the metropolitan areas within each zone. For the purposes of this report the original Montgomery figures, which were expressed as total costs, have been converted to a per capita basis using the 1992 population of the USA (253 million); and then converted to Australian dollars, using an exchange rate of 1 A$ = US$0.75. (It should be noted that the estimates do not include site preparation, administration, legal, land acquisition or permit costs. Vacant land, construction activities and stormwater components of recently-constructed facilities are not included. Also, BMPs installed at industrial or municipal sites are excluded.)

<table>
<thead>
<tr>
<th>BMP Level</th>
<th>Capital Costs ($A per capita)</th>
<th>Annual O&amp;M Cost ($A per capita)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Institutional and non-structural</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>B. A + increased maintenance</td>
<td>1</td>
<td>171</td>
</tr>
<tr>
<td>C. B + minor structural controls</td>
<td>437</td>
<td>453</td>
</tr>
<tr>
<td>D. C + detention basins/wetlands</td>
<td>479</td>
<td>473</td>
</tr>
<tr>
<td>E. D + removal of microorganisms, nutrients and metals by treatment</td>
<td>2137</td>
<td>2850</td>
</tr>
</tbody>
</table>

Source: Montgomery, 1992

It is clear that blanket coverage of all USA cities to Level E (full treatment) would be prohibitively expensive. The Montgomery report concluded that the BMPs must be selected carefully to provide the highest value for money spent. Economic analysis must consider operational and maintenance costs as well as capital expenditures, as these constitute the greater part of total costs at all treatment levels considered.
18.1.2 Australian Studies

The NSW Government Pricing Tribunal has estimated the costs to Sydney Water of stormwater measures for achieving certain quality-of-service targets in the State (NSW Government Pricing Tribunal, 1993a). Results are summarised in Table 42.

It is noteworthy that the bulk of anticipated expenditure for improving stormwater service quality was for flood protection. Out of the total of $765 million in capital costs only $43 million was for stormwater pollution control. However, most of the expected operating cost increases were for stormwater management: $21.0 million out of a total of $31.2 million.

Table 42. Indicative costs of improved service quality of stormwater drainage in NSW

<table>
<thead>
<tr>
<th>Options</th>
<th>Indicative Incremental Capital Cost ($m)</th>
<th>Indicative Increased Operating Cost ($m/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:100 year flood protection in Newcastle, Gosford, and Wyong</td>
<td>70.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Sydney water to manage local government catchments</td>
<td>nil</td>
<td>10.0</td>
</tr>
<tr>
<td>Storm channel flood mitigation in Sydney</td>
<td>411.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Warragamba dam wall</td>
<td>241.0</td>
<td>nil</td>
</tr>
<tr>
<td>Reduce pollution in Sydney Water catchments</td>
<td>43.0</td>
<td>11.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>765.0</td>
<td>31.2</td>
</tr>
</tbody>
</table>

Source: Government Pricing Tribunal of NSW, 1993a

In 1994, the Sydney Water Board proposed a catchment-based charging system for stormwater and drainage services. Under this proposal the costs of addressing flood mitigation and water quality problems would be recovered from water consumers in the catchment area. The amount to be paid by an individual customer would vary depending on the area of land occupied, and the scale of expenditure in the catchment. Charges per customer (not per capita) were estimated to be in the range $47.50/yr to $398/yr. Implementation of this proposal would require community support. The Sydney Water Board was forced to withdraw a proposal for a flat $60 charge in the catchment of Cabramatta Creek following opposition by residents. The bulk of the planned expenditure was to be for flood mitigation.

Sydney Water (1994) has outlined the costs of achieving a higher level of control on sewer overflows, with resultant improvements to ocean, beach, river and estuarine environments. The incremental costs could be up to $3 billion, if containment to the level of the once in two-year event were sought. These costs would be for the following items:
- limit tree root and silt ingress to sewers, and rectify equipment failures
- repair leaky customer house service lines
- repair gross main sewer defects and rapid inflow sources
- repair slow infiltration sources to main sewers
- storage of excess volumes in ponds and tanks
- installation of relief sewers, and
- treatment of excess flows before discharge to nearest waterway or ocean.

Expressing the figure of $3 billion as an annuity of approximately $300 million and dividing by the population served by Sydney Water, the per capita annual cost of full treatment of sewer overflows would amount to approximately $82 per year (or around $200 per customer). This exceeds the average willingness to pay for stormwater quality improvement suggested by contingent valuation studies by a factor of approximately 3. The example serves to illustrate the very large costs of sewer upgrades, and the need for some rationale for deciding what scale of investment is warranted. The property-rights approach to reform (see section 18.2) cannot escape this basic question of appropriate resource allocation to pollution abatement.

The prospects for improvement in total water cycle management in new developments appear much brighter than in retrofits of existing urban areas. Mouritz (1995) presents the results of a detailed cost comparison between (i) ‘conventional’, (ii) ‘proposed’ and (iii) ‘towards sustainable’ designs for an urban redevelopment site at Palmyra in Perth. The third of these was based on the Water Sensitive Urban Design Guidelines (Moran, 1993), which emphasise the need to integrate water and land use planning at a strategic level in the urban planning process. For the Palmyra site, there were only small differences in capital and operating costs between the three options.

Thomas et al., (1994) developed cost comparisons for conventional and water-sensitive designs for the MFP Adelaide development at Greater Levels, which suggested that on-site costs would be slightly higher for the water sensitive design. Gibert and Maheepala (1995) demonstrated that there would be cost savings in the wider Adelaide system if the water-sensitive designs for Greater Levels were to be adopted.

18.2 Applying Economic Principles to the Problem of Stormwater Management

Two strands of economic thought that may be applied to questions of stormwater management are discussed. The first, which draws on market economics and property rights theory, is concerned with institutional structures, including pricing and incentives, to encourage improved management. The second is concerned with the justification of (mainly public) expenditure programs in terms of their scale, timing, and impacts on gainers (beneficiaries) and losers (those who bear the burden of costs).

18.2.1 Market economics

For the market economists, the stormwater problem revolves around the public good nature of stormwater services. The major benefits of stormwater management are public health, reduced damages from floods (including damages to property and
income-producing activities), and enhanced environmental amenity (including enhanced property values from better urban landscapes, greater supply of recreational waters, and higher ecological values). Some also see paid and voluntary employment in work related to drainage systems as a *benefit* of a more participatory approach.

The nature of these benefits poses a problem for the market economists, because:

- they are a public good whereby many individuals receive the benefits
- it is not possible to prevent any individual from enjoying them, and
- benefits received by one individual do not reduce those of another.

For these reasons it is not possible to price stormwater services as a normal good. As stated in a report of the NSW Government Pricing Tribunal:

> To the extent that each individual is enjoying benefits or imposing costs that cannot be individually identified, a flat charge [for stormwater services] across the community may be an appropriate response *(Government Pricing Tribunal of NSW, 1993b)*.

Market economists addressing stormwater management problems have therefore emphasised the better definition of institutional roles. For example, the NSW Government Pricing Tribunal (1993b) has recommended:

- **Integrated environmental regulation**: including the treatment of non-point source pollution on the same basis as point sources by licensing discharges from stormwater drains
- **provision of explicit standards for stormwater and sewer overflows by governments**: either in conjunction with transferable pollution entitlements (not currently considered feasible) or as a part of the urban development consents process. The standards would need to take account of economically feasible technologies and the costs of stormwater pollution reduction relative to those for abating other sources of water pollution.
- **decision making based on stormwater catchment areas**: thereby internalising the public good aspects within the basin, reducing free-rider and enforcement problems
- **clear allocation of accountabilities and responsibilities**: especially clarifying ownership, and favouring the allocation of all responsibility for works and operational matters to the municipal government level, and
- **region-based pricing**: in particular the incorporation of the costs of stormwater infrastructure (based on target service level) into developer charges for new urban developments; and alignment of charging structures with defined responsibilities and accountabilities for existing areas.

Section 19.3 returns to the question of institutional structures.

### 18.2.2 Public sector economics

Given the difficulties of providing market signals to individuals and organisations about the costs and benefits of stormwater management, and given the potentially large public and private sector costs of dealing with stormwater management problems, stormwater management cannot be taken out of the realm of public sector
decision-making simply by ‘marketisation’ of the problem. Consideration of the economic dimensions of stormwater management initiatives will thus require an analytical framework grounded in public sector environmental economics.

Environmental economics, based on social welfare economics, provides a framework for estimating the damage and abatement costs of a stormwater program for a given catchment. The principal outcomes of stormwater management are:

- the level of flooding
- water quality in different parts of the catchment, as related to beneficial uses and environmental values (which presumes some method of water allocation to alternative uses), and
- urban landscape amenity, including ecological benefits.

For each of these outcomes it is possible to compare the total abatement and damage costs of alternative stormwater management programs in the catchment. Total abatement costs are the sum of discounted capital and operating costs needed to attain (and maintain) a given level of performance. As the target level of abatement is raised, the abatement cost will rise. Total damage costs are the costs incurred by society at given levels of effective abatement. For example, the costs from property damages will be higher if abatement expenditure is limited to the containment of the 1 in 20 year flood, rather than the 1 in 50 year flood. Thus, as abatement expenditure is increased, damage costs decrease. The economic problem is to determine a stormwater management plan which minimises the sum of the damage and abatement costs for society as a whole. That is, to recommend increased public or private expenditure on abatement when it is justified by estimated damage reduction; and, conversely, to recommend against abatement expenditure where this is not justified by the potential reduction in damages in society as a whole.

A similar framework may be applied in relation to the objective of water quality, except that the analysis must inevitably be concerned with a vector of water quality outcomes across the whole catchment for a particular stormwater management program. Thus, on the damage cost side it becomes necessary to identify how each beneficial use or environmental value is affected at the given level of abatement expenditure.

There are several reasons why the formulae of environmental economics, above, are not easily adapted to the problem of determining an optimal stormwater management program in a catchment. The natural dimensions of each of the three outcomes of a stormwater management program described above are different in each case: for flooding the appropriate metric is a target flood frequency; for water quality it is a vector measurement of physical, chemical and biological parameters, and this may be expressed either as a limit, as an average, as a load or as a concentration. There is no generally-accepted metric of landscape or ecological quality.

There is, however, progress in environmental valuation. The NSW EPA has developed a bibliographic reference tool, named ENVALUE (New South Wales Environmental Protection Authority, 1995), that will help environmental economists to quantify use values as a function of water quality. In the UK, the National Rivers
Authority has established a methodology for assessment of the benefits of water quality improvements at the level of individual river/stream reaches (Foundation for Water Research, 1994). This is reported to provide robust results, in the sense of (i) providing reproducible estimates when the method is applied by different analysts, and (ii) gaining agreement from stakeholders (Newsome, 1995, pers comm).

Other issues that public policy makers, such as the boards of catchment management bodies, have to take into account include questions of financial practicality, such as how money is to be raised to undertake works; equity questions, such as accessibility of the improved catchment features to the population at large, and who is to bear the burden of costs; and intergenerational questions such as whether it is fair that the current generation bears the burden of costs while only future generations may enjoy the full benefits, due to the lag in ecological response times.

In the face of such complexity, one might conclude that a stormwater management program which is well-based in terms of hydrology, hydraulics, ecology and landscape design, which captures well-informed public support and is do-able in terms of available financial resources may be as much as can be expected in many cases. Nevertheless, given the multiplicity of the components of any stormwater management plan, some overall assessment framework encompassing bio-physical, economic, equity and other issues is needed. Multi-objective analysis that takes account of expected bio-physical outcomes, projected abatement expenditure levels, specific damage costs, and other features of the plan that are not measured in monetary terms is one such framework.

18.3 Financing Stormwater Management Programs

Internationally, there are many examples of the ‘polluter pays principle’ in financing stormwater management programs.

In the USA Alameda County and Santa Clara Valley programs, the founding municipalities contribute funds on the basis of their estimated total annual runoff production. Other catchment bodies collect rates from property owners based on the amount of impervious area on their land. The City of Orlando, Florida uses an Equivalent Residential Unit as its basis for monthly charging for stormwater services. Similar charging systems have been investigated by Melbourne Water. However, it is noteworthy that Melbourne Water already receives drainage rates, and this source of revenue would presumably be surrendered on the introduction of a new system. The incentive-pricing effect in the above cases would appear to be weak, and transaction costs could be high.

A more active form of polluter pays principle has been applied in the German State of North Rhine-Westphalia, in the Ruhr area, where catchment bodies owned by constituent municipal governments are regulated by the State (Lander) government according to predetermined water resource standards for quantity and quality of runoff. Failure by the catchment body to meet the prescribed standards results in a fine, the burden of which is passed on to the municipal owners. The level of fines is calibrated with estimated abatement costs, and revenue from the fines is earmarked for the financing of
abatement measures. This structure has the advantage that the catchment bodies can consider a range of stormwater management strategies for meeting the target outcomes, whereas the number of options available to individual households or organisations is more limited. Therefore the incentive pricing effect can be significantly greater, while there can also be some economic evaluation of the appropriate level of the pollution tax.

Vital issues need to be addressed regarding the appropriate scale and composition of stormwater management programs, and these can only be properly resolved through some judgement about whether the projected abatement expenditures needed to attain various target levels of outcome, are justified in natural or economic terms. The amount of economic resources allocated to urban stormwater management should be increased in line with required abatement expenditures. Environmental economic analyses of the appropriate level of abatement expenditure should be undertaken.

Best Management Practices (BMPs) must be selected carefully to provide the highest value for money spent. Economic analysis must consider operational and maintenance costs as well as capital expenditures, as these constitute the greater part of total costs at all treatment levels considered.

There should be reform of existing drainage rating systems, which should be replaced by charges on households and organisations which more accurately reflect the costs of planned stormwater management programs.

18.4 Conclusions

As a starting point it is recommended:

That research be sponsored to estimate the abatement costs of stormwater management programs for a selection of Australian catchments, a vector of target water qualities and a range of flood frequencies.

A range of policy instruments are recommended to address the stormwater management problem. These include: integrated environmental regulations, the provision of explicit standards for stormwater and sewer overflows by governments; decision-making based on stormwater catchment areas; clear allocation of accountabilities and responsibilities; and region-based pricing. Before such practices are enforced in a catchment area, the relative merits (or otherwise) of the different approaches must be assessed.

Given the multiplicity of the components of any stormwater management plan, some overall assessment framework encompassing bio-physical, economic, equity and other issues is needed. Multi-objective analysis, that takes account of expected biophysical outcomes, projected abatement expenditure levels, specific damage costs, and other features of the plan that are not measured in monetary terms is one such framework.

19. INSTITUTIONAL ARRANGEMENTS FOR STORMWATER MANAGEMENT

The COAG partners have committed themselves to a number of principles for institutional development in the water sector. This sub-section elaborates these principles in the context of stormwater management. The next two sub-sections deal,
with (i) current institutional arrangements for stormwater management in Australian jurisdictions and (ii) those in Germany, England and USA. Finally, some conclusions and recommendations for institutional development for Australian stormwater management are put forward.

19.1 COAG’s Institutional Principles for Water Resources Management

Drawing from the Report of the Working Group on Water Resources Policy dated February 1994, the principles already endorsed by COAG are that:

- roles and responsibilities should be clearly separated in different institutions for different purposes
- community involvement in water resources management is essential, and
- management and planning needs to be based on a whole-of-catchment approach.

These principles are discussed in more detail below.

19.1.1 Separation of roles and responsibilities

In its unpublished report to COAG dated February 1994 the Working Group on Water Resources Policy stated (para 3.9):

*While some jurisdictions are moving to change the institutional arrangements ... to delineate more clearly the role and responsibilities of the various players, there is still a deal of overlap in some areas in relation to the trustee for the resource, establishing and enforcing regulatory requirements, and service delivery. In a first-best or ideal world it would be desirable for each of these functions to be undertaken by separate entities. The alignment of organisational structures with objectives, means separated bodies can be provided with clear and non-conflicting objectives and more transparent accountability mechanisms...*

19.1.2 Community involvement

The Working Group stated (para 3.12) that:

*Community involvement is seen as important in gaining public recognition of the challenges facing the nation the proper management and use of our water resources and in securing community support for the solutions proposed.*

19.1.3 Integrated catchment management

The Working Group recommended (para 4.12) that:

*If natural resource management is to be pursued in an integrated manner... there is a requirement for those jurisdictions where institutional arrangements of this nature have not yet been put fully in place, to consider doing so.*

Many detailed issues must be resolved in implementing these institutional principles.
In terms of the first principle, the implied separation of powers and responsibilities seems to be between a body dedicated to the achievement of efficient and effective multi-purpose planning and management of stormwaters, and other bodies dealing with water supply, sewerage, urban development plans and environmental protection. Some of the questions that need to be resolved include:

- what level of government is appropriate for the urban catchment management function: local authority, catchment board or state government department?
- what should be the statutory, corporate and fiscal status of the catchment body?
- what ministerial powers should apply to the catchment body?
- what powers should be exercised by the catchment body?
- what relationship should exist between the catchment body and the environmental regulator. (for example, should the catchment body set water quality targets for receiving waters?)
- what relationship should exist between the catchment body and the natural resource management department (for example, which institution should determine water allocations?)
- what relationship should exist between the catchment body and the urban development planning agency (for example, should the catchment plan, if one is produced, have statutory status for land use planning?), and
- should there be any attempt to introduce a polluter pays principle?

Before commenting further on such questions, the following sections will summarise current institutional arrangements in some overseas jurisdictions and in Australia.

### 19.2 Institutional Responses in Other Countries

Given the multiplicity of technical options and actors it is hardly surprising that there has been a call for integrated management. ‘Integration’ is nevertheless a fuzzy concept, which needs to be better defined in particular regions. While institutional structures vary between countries, two powerfully integrating concepts are:

- integrated catchment management, and
- stormwater management programs.

Stormwater management programs are an attempt to specify all the actions that are needed to improve stormwater management in an area, and to identify who is to be responsible for implementing them. The development of a program approach is useful in lending coherence to the set of required actions. It also is useful in maintaining progress against a targets of achievement, even if the exigencies of funding availability cause delays to the program.

All countries visited have been adapting their institutions to address the problems of urban water management. The general trend has been to make sharper institutional distinctions between planning, regulatory and operational functions for urban stormwater services. The need for planning and operational mechanisms at stormwater catchment scale has been recognised everywhere, though the particular organisational forms have varied, depending mainly on the structures of government and the water industry. All countries recognise that public involvement is an essential input in the
development and implementation of improved urban water resources management. There has been less consistency with regard to the incorporation of economic instruments and property rights theory in stormwater management.

19.2.1 U.S.A.
The USA’s arrangements for stormwater control are of interest in Australia, as an example of a three-tier government system (federal-state-local) that has adopted new institutions during the last decade.

The general framework within the USA is provided by the US Clean Water Act 1971, amended 1987, which is national legislation binding on the states, under which discharges from storm sewer systems serving populations of 100 000 or more require permits within the National Pollution Discharge Elimination System. In many cases, responsibility for administration and enforcement is vested in a state government. Local governments, generally termed ‘municipalities’ are deemed to be the owners of these systems, and are the prime targets of the legislation. In addition there are 11 categories of industrial discharges which also require NPDES permits. The US EPA estimates that there are about 100 000 industrial facilities that now fall within the NPDES. (On a crude per capita basis this would imply around 5000 industrial facilities if the same scheme were applied in Australia). Agricultural activities (including irrigation return flows), and uncontaminated runoff from oil, gas and mining operations are statutorily excluded from permit requirements.

The granting of a NPDES permit depends on the originator of the stormwater discharge demonstrating that the point-source effluents are acceptable in the context of receiving water impacts, or may be abated through an agreed program of stormwater management. Thus:

> the NPDES permitting authorities are directed to ensuring that municipalities develop and implement stormwater management programs to control pollutants to the maximum extent practicable. (United States Environmental Protection Agency, 1992 p. 10)

The US EPA regards the joint definition of the stormwater management program between the NPDES authority and the municipality as giving flexibility to the permitting process. However, Montgomery Consulting Engineers (1992) reported that one of the key concerns of municipalities is the unknown cost to implement best management practices (BMPs), because the level of required pollutant reduction is currently unknown.

There is currently uncertainty about future coverage of the NPDES. In 1992 it was planned to extend the system to smaller municipalities (that is, those having under 100 000 population), and a greater range of industrial/commercial/utility activities. Such extension clearly involves a choice about the appropriate form and delegation of the permitting process. For example, by contrast, the National Rivers Authority in UK and Lander Governments in Germany only concern themselves with regulation of discharges at a macro level, leaving issues of system design, bye-laws, local trade offs and enforcement to local institutions, whether these be catchment authorities, water utilities or local governments.
19.2.2 Germany

Germany has a three-tier federal government system, comparable to that in Australia. For more than twenty years Germany has led European Community environmental standard setting, and has implemented a polluter pays approach to surface water pollution.

For water management Germany has a system of federal-level ‘frame’ laws, which establish overall water quality guidelines. Individual states (Lander) then enact their particular versions of the federal law, and, as in Australian states, responsibility for the implementation of policies and enforcement of environmental law resides at state level. At that point the similarity ends. At the state level, while there are differences in approach among the various Lander, they each enforce the polluter-pays principle by empowering state environmental departments to establish, in conjunction with local water managers, catchment water quality objectives, which must be achieved or a fine is payable.

In the state of North-Rhine-Westphalia, this system has been further refined by the establishment of catchment agencies. These are statutory bodies which provide water infrastructure and catchment management functions, and they obtain their funding from the municipalities which fall within their catchment area. The catchment agencies are regulated by the environment department, and pay fines for failure to achieve agreed water quality targets. This institutional system has five advantages:

• there are clearly defined responsibilities and accountabilities between regulators, water managers and local government
• planning, management and regulation are performed at catchment scale
• multi-objective planning and management is practised within an integrated framework
• the introduction of incentives for environmental economic efficiency via the polluter pays principles is straightforward, and
• catchment agencies are sufficiently large as to incorporate a critical mass of water management competencies and scale economies.

19.2.3 England and Wales

Institutional developments for water resources management in the UK are of interest in Australia, partly because of the common system of parliamentary government, and also because of the water reforms which have been implemented in the UK over the last decade. Only England and Wales are considered here as there are different arrangements in Scotland and Northern Ireland.

In England and Wales environmental regulations, administered by the National Rivers Authority (NRA), are based on the ‘beneficial water use’ concept, similar to the concept of ‘environmental values’ used in the Australian National Water Quality Guidelines. The NRA is responsible for monitoring water quality, and may require the (privatised) water companies to do any necessary work to meet environmental requirements. There is generally a policy of encouraging industries and commercial centres to discharge to sewers, and this means that the NRA almost exclusively deals with the water companies, who in turn have powers to control discharges by industry and
commerce within their catchment areas. The water companies, though privatised, were set up on the basis of the major catchment areas. Occasionally, the NRA deals directly with industries which discharge to a surface water body, but the extent of this regulation appears quite small when compared with the amount of direct regulation of industries practised in the USA under the NPDES. The relationship of the NRA to the water companies appears similar to that of the Lander environmental departments to the catchment authorities in Germany, except that in England and Wales, instead of a fining system, the NRA may require a water company to undertake particular works.

The UK water companies are required to submit Asset Management Plans to the Office of Water Services (OFWAT), the economic regulator for the industry, and these identify all planned upgrades to sewage and drainage infrastructure. A form of polluter pays principle is thus in place, through the licence conditions, including treatment requirements, imposed by the NRA on the water companies. The water companies, in turn, pass the costs on to water consumers, provided that the industry regulator, OFWAT approves. In order to cover monitoring costs, the NRA levies an administrative charge, based on volumes discharged by each water company (Crabtree, pers comm). This model is not dissimilar to that now in place in New South Wales, where a request from government to a water utility to undertake environmentally directed works can be recognised as a community service and submitted to the New South Wales Prices Tribunal for approval of concomitant water/sewage/drainage price increases.

In an effort to help water utility managers cope better with sewer discharge requirements, the UK-based Water Research Foundation has prepared an Urban Pollution Management Manual (UPMM) (Tyson et al., 1994). This represents the culmination of some 10 years’ investigation and development work on the design and performance of urban wastewater systems (sewage and stormwater). Clifford and Morris (1995) describes the UK institutional arrangement, and the role of the UPMM within it. A most significant aspect of the Manual is that it sets out an evaluation process that fully integrates environmental impacts with wastewater/stormwater system design.

Recently, in parallel with its regulatory functions described above, the NRA has initiated a catchment planning and management strategy. Since many of the catchments in England and Wales are urbanised, this is highly relevant to a consideration of Australian urban catchment management. Chandler (1994), describes the NRA’s integrated Catchment Management Planning Strategy.

The main advantages of the NRA catchment plans are that they (i) summarise information on catchment conditions, (ii) articulate the existing management priorities of the managing authority (that is, the NRA), (iii) identify issues, (iv) identify possible future management responses, detailing agency, urgency, and timing, (v) put in place a consultation process that should lead to better coordination of policies among the various actors who influence the catchment uses and condition, and (vi) provide a framework for multi-functional planning.

From an Australian view point, weaknesses of the NRA system seem to be that (i) there is no obvious framework for the resolution and ‘closure’ of issues, (ii) the catchment plans have no formal status in the statutory town planning process (for
example, in contrast to the statutory status of stormwater management plans required before issue of NPDES permits in the USA), and (iii) frameworks for broad public involvement do not seem well developed.

The NRA system combines the role of catchment planner and environmental regulator within the same institution. This contrasts with the American framework in which the environmental regulators do not so obviously engage in catchment planning, but rather concentrate on the permitting function through which individual wastewater utilities and owners of municipal drainage schemes must explain how their plans and current activities are, or can be made, consistent with prevailing environmental standards or guidelines. This may fall short of a complete catchment analysis, if, for example the discharge affects just a particular reach of a river.

Local government is not much involved in stormwater management in the U.K. The Construction Industry Research and Information Association have, however, developed a set of guidance documents for developers and construction companies, dealing with source control and pollution aspects. There are signs that town planners are taking increasing interest in improved management of the urban water cycle in order to create amenity values. The National Environment Research Council is taking a part here, as set out in Rees (1994).

19.3 Institutional Arrangements in Australia

Throughout Australia, institutional arrangements for stormwater management are currently in a state of flux as the various jurisdictions adapt to the National Water Reform Agenda. There is now an opportunity to adapt these institutions to meet the challenges ahead.

It is not unreasonable to state that across Australia, arrangements for integrated stormwater management are generally chaotic. Among all the fields of water resources management this must require the most urgent institutional change. Control is generally very fragmented and there is a lack of clear accountability for various parts of the water cycle. The relationships between the various operators, regulators, and councils is often blurred, and in many cases the operating agencies are also involved in standard or target setting. There is therefore an urgent need to improve the institutional framework for stormwater management.

Local authorities have traditionally played a dominant role in providing drainage and flood control in the context of land use planning. But in some cases, this responsibility has been taken over by State government agencies, especially where some major catchment is involved. In some jurisdictions drainage and flood control are provided entirely by state or territory agencies, and local government plays no direct role. In all jurisdictions drainage, flood control and more general stormwater management functions are nested within quite complex institutional arrangements for natural resources management, environmental protection, and land use planning. The following sections summarise the situation in each jurisdiction.
19.3.1 Australian Capital Territory

In many respects the water sector institutions in the ACT have developed along lines that are broadly consistent with National Water Reform Agenda. This includes:

- separation and corporatisation of the water service provider, ACTEW
- integrated land and water planning through the Territory Plan
- catchment based strategic assessment
- incorporation of appropriate stormwater management structures, to ensure identified environmental values are not compromised, at the development stage
- land use management and planning guidelines including floodplain management guidelines, and
- implementation of a regulatory regime to ensure water quality protection.

The objectives of the ACT Water Policy Plan 1991 comprised the conservation of water as a scarce resource, and its equitable allocation in meeting a range of community needs, without detriment to the environment. Major components of the water quality strategy were as follows:

- designation of water uses and conservation values a basis for determining permissible uses and management practices
- identification of the level of water quality which would support the acceptable uses
- provision of sewage and stormwater infrastructure that would be responsive to the protection of in-stream uses and conservation values, and
- integrated, total catchment-based planning and management.

The implementation strategy outlined in the Policy Plan comprised a suite of measures determined on the basis of cost effectiveness, social equity, and effective attainment of objectives. The measures included:

- designation of water use and conservation values
- water quality guidelines
- all urban and industrial areas to be sewered
- upgraded sewage treatment facility
- stormwater pollution control measures
- controls on soil disturbance during construction
- rural soil conservation
- licensing of all point source discharges
- waste minimisation through re-use of treated wastewater
- approval of land development proposals to take account of downstream impacts
- protection of floodplains and riparian vegetation, and
- provisions for monitoring, review and feedback.

There is currently significant organisational restructuring occurring in the ACT. Revised institutional arrangement now being developed are intended to enhance effective and coordinated water resource management. The arrangements will assist an integrated approach which will foster overall efficiency in resource use while ensuring appropriate environmental protection.
19.3.2 New South Wales

The discussion in this section is taken largely from James et al., (1994).

Responsibilities for management of the water cycle in New South Wales are divided among numerous government agencies, including:

- a Stormwater Coordinating Committee
- urban and rural local councils, which operate water, sewerage and drainage facilities across the State
- corporatised water supply authorities, including Sydney Water and Hunter Water Corporation
- the new Department of Land and Water Conservation, which includes the former departments concerned with Water Resources, Public Works, and Conservation and Land Management
- the EPA, which has statutory responsibility for environmental protection, water quality (through the Clean waters Act) and pollution control (through the Pollution Control Act and the Environmental Offences and Penalties Act, 1989). These acts deem pollution of water to be an offence unless licensed by the EPA, and prescribes penalties
- various urban catchment management committees, formed under the Catchment Management Act, and the Hawkesbury Nepean Catchment Management Trust, which was formed under its own Act. New legislation is proposed for the establishment of a Catchment Commission, and
- in many cases the preventative programs relating to stormwater management need to be instituted through the land-use planning process which is the responsibility of the Department of Planning, under the Environmental Assessment and Planning Act.

Regulatory responsibilities for water quality management are defined under the Clean Waters Act. Part 3 of the Act provides a four-level classification, with prescribed water quality standards for discharges to each classification level. Some ambient water quality criteria are also set out (for example, faecal coliform density in recreational waters). The principal urban areas are classified under this scheme.

Environmental Impact Statements are being prepared on the operation of sewage overflows from each of Sydney Water’s 36 sewerage systems, as a part of the licensing process for sewer overflows. The New South Wales EPA will determine license conditions, based on an examination of options to be presented in the statements.

The idea of licensing urban stormwater runoff in the Hawkesbury-Nepean Basin has been canvassed by James et al., (1994). They recognise that it is not feasible to directly regulate the myriad of urban runoff sources. However, discharge points for stormwater drains could be licensed, as occurs in the USA under the NPDES. The major difficulty in this is identifying who actually owns or controls stormwater drains, which often run through several local council areas. Extending NSW regulatory or incentive schemes in the Hawkesbury-Nepean to include urban runoff as well as possibly extending controls on agricultural runoff and introducing incentive charges on effluents, would involve the following administrative steps:
• establishing a pilot scheme which would involve the Hawkesbury-Nepean Catchment Trust, local councils, the EPA and Sydney Water. Early tasks would be to improve estimates of pollution loads, and to trial a number of control options including retention basins, infiltration systems and wetlands. The authors acknowledged that the cost and effectiveness of the suggested controls still needs to be examined
• the EPA would be required to develop a system of discharge licenses for trunk drains, including assignment of pollution contributions and compliance responsibilities to local authority areas within any given drainage system, and
• the local council should be obliged to undertake compliance monitoring.

It is noteworthy that the above suggestions fell short of recommending the creation of new stormwater catchment bodies, as is being done in South Australia. Clearly, the authors felt that the Hawkesbury-Nepean Trust, even if given wider roles and responsibilities vis a vis local governments in the basin, was not a suitable target for regulation and licensing by the EPA. By contrast, this is exactly what has happened in Germany where catchment bodies, formed from constituent local authorities, are subject to regulation by Lander EPA’s under a polluter pays system.

The issue of appropriate scale for a catchment body in the Sydney region has been addressed by Ribbons (1995). Having assessed the likely capital and operating costs of a system of wetlands and detention basins in the Cabramatta creek catchment, Ribbons concluded that a George’s River Catchment Trust (that is, a body for the wider catchment of which Cabramatta Creek is a tributary) would be a more viable organisation than one for Cabramatta Creek alone. This would be a similar size of organisation to the Upper Parramatta River Catchment Trust, and could address stormwater quality as well as flood control issues. Moreover, by considering the whole George’s River catchment the danger of ‘overkill’ in a sub-catchment might be avoided.

The New South Wales EPA has been investigating a system of load-based licensing, based on:
• cost modelling to determine compliance costs and charge levels
• community consultation
• establishment of suitable monitoring systems
• extension of licensing systems, and
• extension of existing license fee collection systems.

In its licensing functions, the EPA is not unlike the National Rivers Authority, which licenses discharges from combined sewer systems in England and Wales. There, catchment plans are developed under the leadership of the NRA itself, so there is direct feedback from catchment planning and management into licensing policies and practices. In New South Wales, the relationship of the EPA to the Catchment Trusts is indirect.

The need for coordination at the sub-metropolitan scale is evidenced by the formation of the Sydney Coastal Councils Group in 1989. This consists of fifteen councils with
harbour and sea foreshores. The Group recently adopted a four-year forward plan in order to promote sustainable management of the urban coastal environment. The primary objectives are to:

- coordinate and facilitate information exchange
- enhance community awareness
- expand the role of local government in managing the urban coastal environment
- represent the interests of member councils, and
- develop and implement strategies for integrated and sustainable management, including reduction of water pollution and conserving/improving stormwater and sewage infrastructure.

The Group’s main activities have been:

- preparation of guidelines on regional management of stormwater
- design investigations for stormwater pollution interception and treatment
- publication of a stormwater pollution control pamphlet aimed at the broader community, and
- submissions to State and Commonwealth governments.

While the Councils’ initiative in setting up the Group is laudable, the question remains as to whether such a voluntary association has the necessary statutory and fiscal powers to fully implement appropriate stormwater management programs: for example, in relation to the implementation of economic instruments for pollution reduction at source or in relation to financing expenditure on pollution abatement programs.

19.3.3 Northern Territory

In the Northern Territory, responsibility for all water management functions rests with the Power and Water Authority. Given the relatively small size of Darwin and Alice Springs and the development stage of the Territory this probably remains the appropriate institutional framework.

19.3.4 Queensland

In Queensland responsibility for stormwater management lies with local government. However, there is a severe mismatch between catchment areas and local government areas. Typically, a catchment will include a number of local government areas. Historically, local governments have been responsible for drainage management, with the Queensland government playing a major role in floodplain management. In future, local governments will need to provide stormwater management plans for urban areas which deal with both quantity and quality. The Queensland Department of Environment and Heritage will provide guidelines for urban stormwater management to support the proposed Environmental Protection (Water) Policy requirements.

Most urban wastewater discharges to the receiving environment will be licensed under the Environmental Protection Act 1994. The Department of Primary Industries provides water resource management functions for rural areas (that is, integrated catchment management).
19.3.5 South Australia

Stormwater management arrangements in South Australia have been summarised by Rolls (1995). Responsibility for floodplain and watercourse management lies almost entirely with local government, under the Local Government Act 1932. The State government has assumed responsibility for these functions in the Murray, North Para and Little Para Rivers, following proclamation under the Water Resources Act 1990. There are 119 local government Councils in the State, serving a population of 1.4 million. The state has subsidised drainage related works through a Drainage Subsidy Scheme established in 1967.

Although this scheme included an Advisory Committee, arrangements were not conducive to the integrated, multi-objective management of stormwater. Total expenditure under the scheme was modest, many local authorities lacked the necessary skills and experience to undertake stormwater planning, and hardly any of the local government boundaries coincided with catchment boundaries. Recognising the limitations of these arrangements, several local authorities banded together to form drainage management bodies. These were constituted formally as controlling Authorities under Section 200 of the Local Government Act 1932. But they saw their function to be drainage and flood control, rather than general resource managers, and their activities were not well integrated with land use planning. The result was that integrated stormwater management was not achieved, and there are many examples of single-purpose, single-agency works. Opportunities for stormwater detention, re-use and naturalisation of tributaries have been wasted.

South Australia is currently implementing a new Catchment Water Management Act, the major features of which are as follows:

- Catchment management boards, which are statutory authorities responsible to the Minister for the Environment and Natural Resources, are to be established.
- Membership is to be determined according to the number of local authorities in the catchment. The chair is to be nominated by the State Minister in consultation with the President of the Local Government Association; with an equal numbers of nominees from Councils and by the Minister.
- Board areas are to be whole catchments.
- Board responsibilities shall cover all water resource management functions, including allocation, as well as stormwater management.
- Boards must develop catchment management plans, to be reviewed annually.
- Funding is to be partly from State government, but also to include a contribution from the constituent Councils, through a levy on ratepayers.

Initially, Catchment Management Boards are to be established for the Torrens and Patawalonga Catchments, which have the highest community profile in terms of their water quality problems. Responsibility for the Drainage Subsidy scheme is to be transferred to the Minister for the Environment and Natural Resources.

19.3.6 Tasmania

Stormwater management in Tasmania is the responsibility of local authorities. To date these have concentrated issues of wastewater disposal rather than improved stormwater management.
19.3.7 Victoria
Responsibility for stormwater management in the Melbourne region currently rests with Melbourne Water. Melbourne Parks and Waterways shares responsibility in respect of certain areas under its designated control. Under the Victorian Total Catchment Management Program there is also a TCM group for the whole of the Melbourne Region.

There have been some successful initiatives in the Melbourne region, especially with regard to quantity management. Condina and Thompson (1993) give two examples which deserve special mention:

- Delineation of the 1 in 100 year floodplain of the Dandenong Creek catchment (population 800 000), and protection of major remnant portions through floodplain declarations. The floodplains now provide considerable stormwater storage, minimising the need for stream levees, providing formal and informal recreational opportunities and opening up the possibility of further potential for stormwater quality improvement.
- Provision of Drainage Strategies for the South East Growth Areas of Melbourne. These plans are prepared at the greenfields stage, and provide: layouts for the proposed drainage system; inventorisation of physical drainage infrastructure required; delineation of overland flow paths; identification of recreational areas; identification of water quality treatment areas; floodplains and fill levels; and finally plans for retention of natural waterways, natural storage zones, wetlands and indigenous vegetation.

19.3.8 Western Australia
Since the early part of this century responsibility for drainage has been shared between water agencies of the State Government and local government. The legislation pertaining to the state agency has been enabling rather than directive in nature, and involvement by the Water Authority and its predecessors in providing drainage has been negotiated with local governments. In recent decades the Water Authority has provided main drainage schemes for new developments, following involvement in the planning process. Local authorities have supplied subsidiary and minor drainage facilities.

From 1982 the Water Authority, and its predecessor the Metropolitan Water Authority, held statutory responsibility for developing the “Arterial Drainage Scheme” for Perth, and this responsibility was carried forward to the Water Bill 1990. Following the recent corporatisation of the Water Authority, responsibility for urban stormwater management, together with relevant staff, has been transferred from the former Drainage Branch into a new Water Resources Commission.

The legislation which established the Arterial Drainage Scheme in 1982 referred to the need for multiple objective planning of drainage, including management of water resources and the natural environment. But it was not until the early 1990s that water sensitive urban design principles enunciated more integrated approaches and extended the concept of ‘drainage’ to total system design in new developments. Western Australia was an early participant in the development of water-sensitive urban design principles, and this is now being reflected in current approaches to the planning of new urban areas to the north and south of Perth.
However, the institutional structure remains one based on the planning and management of natural resources at the State Government level. Surface water catchments have not been adopted as a basis for statutory catchment management bodies involving local government.

The catchment areas of the Swan-Avon River/Swan Estuary and two of its important tributaries, Ellen Brook, and the Canning River are of special significance for the quality of waterways in the Perth Metropolitan Area. Urban consolidation in the Perth-Guildford axis will increase the quantity and range of stormwater contaminants entering the Swan Estuary, and this is likely to widen pollution concerns to litter and toxics, as well as the present focus on nutrients. The Canning River system is visibly under pressure from additional urbanisation in the last decade.

While local groups based on community input have been encouraged, for example the Bayswater Main Drain group, and the Swan-Avon Catchment group, arrangements for integration with statutory land use planning, local government and water resource management at the level of the whole catchment have been ad hoc.

An area of great importance in Perth is the effects of urbanisation on the groundwater resources of the Swan Coastal Plain. This has recently been the subject of a Parliamentary Inquiry, and Environmental Protection Plans. While the natural phenomena in this case are local drainage and infiltration to groundwaters, the objectives and principles of management are strongly akin to those required in urban stormwater management generally.

The Shire of Wanneroo, in the north western corridor, is the fastest growing local authority in the Perth Metropolitan Area. It has established a sub-committee dealing with groundwater and lakes management to address these problems. The Shire of Serpentine–Jarrahdale in the south eastern corridor faces somewhat different problems due to winter ponding of surface runoff on its clay soils. It has been developing a water-sensitive design approach for urban village development that will eventually accommodate some 60 000 people. But institutional arrangements for management remain complex.

19.4 Conclusion

While the application of the principles for institutional development so far enunciated and accepted by COAG is necessary, the principles are not in themselves sufficient for improved stormwater management. Specifically:

- the respective roles of local governments, catchment bodies, state and territory environmental regulators and natural resource managers need to be both consistent and clear
- stormwater catchment bodies should have statutory powers and responsibilities, including powers to raise funds and undertake works and other expenditure deemed necessary
- local government should be formally involved
the roles and responsibilities of catchment bodies need to include preparation of catchment management plans which (i) identify catchment conditions requiring attention, (ii) list possible management responses, (iii) specify a stormwater management program which identifies costs, timelines and the agencies which are to be made responsible for each action, and

catchment bodies should be empowered to set up contractual undertakings by other organisations in the public or private sectors to carry out the catchment management program.

Within most jurisdictions there is a need for extensive reform of the institutional structures for stormwater management. to complement the corporatisation of water utilities. While the application of the principles for institutional development so far enunciated and accepted by COAG is necessary, the principles are not in themselves sufficient for improved stormwater management.

A new approach must separate powers and responsibilities. The success of any one institutional form is bound by several factors, including:

- clear definition of roles and responsibilities
- motivational factors at corporate and individual level
- workable implementation mechanisms
- technical and financial backup, and
- clear perception in the community about the nature of the resource management problem and how it can contribute.

Specifically:
- the respective roles of local governments, catchment bodies, state and territory environmental regulators and natural resource managers need to be made both consistent and clear
- stormwater catchment bodies should have statutory powers and responsibilities, including powers to raise funds and undertake works and other expenditure deemed necessary
- local government should be formally involved
- the roles and responsibilities of catchment bodies need to include preparation of catchment management plans which (i) identify catchment conditions requiring attention, (ii) list possible management responses, (iii) specify a stormwater management program identifying costs, timelines and the agencies which are to be responsible for carrying out each required action, and
- catchment bodies should be empowered to set up contractual undertakings by other organisations in the public or private sectors to carry out the catchment management program.

All jurisdictions need to further develop urban stormwater management in ways that are:

- programmatic
- catchment-based
- involve local government
- include a mixture of structural and non-structural tools, and
- emphasise source controls.

In all jurisdictions the statutory objectives of stormwater management bodies should include flood management, water quality, environmental amenity and ecological integrity. Stormwater management targets should be set with reference to the National State of the Environment Reporting System.
There is a need for stormwater management to be undertaken at either the metropolitan scale, or at the major urban catchment scale. The principle of separation of powers and responsibilities, and the historical and potential future roles of local governments, imply that bodies established for this purpose should be preferably owned by local governments and be accountable to environmental regulators at state/territory level for the achievement of agreed targets within a polluter pays framework. Urban catchment management bodies should have the power to obtain revenue either from local government or through direct charges on households and organisations in the private and public sectors, to employ relevant staff and to commission works. They should also have the power to institute stormwater management bye-laws, including those related to the introduction of economic instruments. They should publish annual reports of their operations and planning activity.

Where not already available, stormwater management programs should be established for all major urban catchments. These should:

- summarise information on catchment conditions,
- articulate the existing management priorities of the managing authority
- identify issues
- identify possible future management responses, detailing agency, urgency and timing
- put in place a consultation process that should lead to better coordination of policies among the various actors who influence the catchment uses and condition, and
- provide a framework for multi-functional planning.

A water quality strategy should involve the:

- designation of water uses and conservation values a basis for determining permissible uses and management practices
- identification of the level of water quality which would support the acceptable uses
- provision of sewage and stormwater infrastructure that would be responsive to the protection of in-stream uses and conservation values, and
- integrated, total catchment-based planning and management.

The Commonwealth should support a new Urban Water Care Movement. Initial components could include:

- a public awareness campaign ($2 million/yr for 3 years)
- educational materials ($2 million/yr for 3 years)
- support for community groups in urban catchments ($2 million/yr for 3 years)
- loan scheme for local authorities engaging in urban catchment management programs ($5 million /yr for 10 years) and
- capital grants for minor capital works which demonstrate pilot schemes; and management methods for water reclamation and integrated stormwater management ($20 million/yr for 5 years).

20. RESEARCH NEEDS

This section highlights a number of areas where the study has suggested the need for further research, or changes in research arrangements. These are given below without further supporting text. The recommendations are not intended to cover all research needs that relate to the very wide topics dealt with in the report, but only to express a number of salient requirements.
The Commonwealth should set up a new Research and Development Corporation for the Urban Environment, including the urban water environment. It should deal with issues of urban water cycle management, water pollution, air pollution, energy use and waste management. The budget should be similar in size to that of the Land and Water Resources Research and Development Corporation, which is focused on non-urban resource management issues.

<table>
<thead>
<tr>
<th>There is an urgent need for a national research project to examine options for improved urban water cycle management and infrastructure cost reduction. This should be supported by the Commonwealth in association with the Water Services Association of Australia.</th>
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<tr>
<th>Research into Australian microbiological species that may be associated with water reclamation projects should be encouraged.</th>
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<tr>
<th>A national survey of community attitudes and knowledge of issues relating to water re-use is needed as a basis for planning further community involvement in water re-use planning and implementation.</th>
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<tr>
<th>There is a growing need for environmental economic studies that (i) demonstrate the community’s willingness to pay for improved water quality in urban regions, (ii) provide estimates of environmental damages associated with the degradation of sensitive environments, and (iii) develop indicative estimates of the cost schedule for ascending levels of abatement.</th>
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<tr>
<th>Further research is needed into the hydrological and ecological implications of effluent and stormwater discharges in sensitive environments.</th>
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<tr>
<th>Research into methods of storage and of seasonal demand equalisation for reclaimed water should be supported.</th>
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</table>

| A case study in a newly-developing urban region should be supported by the Commonwealth in which concepts and prototype designs for integrated urban water resources management are demonstrated. This could be a world-first. |
21. BIBLIOGRAPHY


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APPENDIX A

STUDY WORK PROGRAM

Wastewater
The main components of the work program in producing the study report were as follows:
• a National Effluent Re-use Survey of current (1994) and anticipated sewage re-use to the year 2000 was conducted by Melbourne Water, on behalf of the Water Technology Committee; this was made available to the study. Appendix D reproduces the questionnaire. Except where otherwise stated, all data in tables and diagrams in Part II (Re-use of Wastewaters) are derived from this survey
• WRMC/WTC representatives were nominated from Commonwealth, State and Territory jurisdictions: these provided inputs to the study and reviewed the draft report
• the project leader visited France, Germany, UK and the USA to visit regulatory agencies, utilities and research groups to ascertain latest practices and issues. A report on these visits is given in Thomas (1995a)
• an intensive literature review and industry consultation process was undertaken
• meetings were held with stormwater management agencies and committees in States and territories.

Stormwater
A series of interviews were conducted with agency personnel in each state and territory. The interviews covered:
• a discussion of stormwater management problems
• perceived areas for improved management of stormwaters
• current and emerging institutional structures.

As part of the investigations leading to the production of the COAG Study Report, France, Germany, the UK and the USA were visited in June/July 1995.

The objectives of the visits were:
• to become acquainted with recent technical developments in stormwater management
• to hear about successes and failures
• to ascertain environmental and economic issues in stormwater management, and
• to discuss alternative institutional and regulatory approaches.

Meetings were arranged with water managers, urban planners, environmental regulators, researchers and decision makers. A report on these exchanges is given in Thomas (1995b).

Through personal contacts and formal literature searches, published and grey literature were accessed for all jurisdictions.

Three stormwater conferences were attended during the study period, and contributed papers were utilised in preparing this report:
• Australian Water and Wastewater Association 16th Biennial Federal Convention, Sydney, April 1995
APPENDIX B

TABLE OF WASTEWATER DISPOSAL PRACTICES IN AUSTRALIA WITH SOME INTERNATIONAL EXAMPLES

(a) Disposal to Oceans and Estuaries
(b) Disposal to Inland Waters: creeks, lakes and rivers
(c) Disposal to Wetlands
(d) Disposal to Land
### Australian Wastewater Disposal Practices:
Disposal to Ocean and Estuaries

<table>
<thead>
<tr>
<th>State</th>
<th>Location</th>
<th>Project Details</th>
<th>Findings and Considerations</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>New South Wales</td>
<td>Sydney: Sydney Deep Ocean Outfalls, Bondi, North Head and Malabar</td>
<td>80% of NSW’s population of 5.77m live in the coastal zone in Sydney, Newcastle or Wollongong. Problem areas identified by Zann (1995) are: Sydney ocean outfalls (relocated in 1990), Homebush Bay, Georges River, and Lake Illawarra, Lake Macquarie and Tuggerah Lakes.</td>
<td>The outfalls were part of SWB’s integrated management plan for Sydney’s sewage waste. Monitoring of water quality from 1992 and 1993 shows nearly 100% compliance with proposed bathing water guidelines at major beaches. Viral presence remains north of Sydney Harbour, but is largely absent south of the Harbour. Overall the deep outfalls have contributed to improved water quality. Diluted sewage moves southward and below the water’s surface away from Sydney’s ocean outfalls. Levels of contaminants in fish and deployed oysters along the shoreline have decreased since the deep ocean outfalls were commissioned.</td>
<td>Fagan et al., (1992) Ashbolt et al., (1993) Philip (1995) Zann (1995)</td>
</tr>
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<td></td>
<td>Bondi</td>
<td>In 1990/1991 Sydney’s cliff-face outfalls, which discharged primary treated effluent, were replaced by deep ocean outfalls. Changes in water quality due to the outfalls were to be monitored through a five year Environmental Monitoring Plan (EMP). The four major treatment plants: North Head (1 200 000 people serviced), Bondi (600 000 people serviced), Malabar (1 500 000 people serviced) and Cronulla were all upgraded. North Head, Bondi and Malabar receive 80% of Sydney’s total sewage flow, and the remaining 20% is discharged from smaller coastal and inland treatment plants.</td>
<td>Bondi Beach water quality has improved since the deep ocean outfall was commissioned in 1991.</td>
<td>Sydney Water Board (1994b)</td>
</tr>
<tr>
<td></td>
<td>Sutherland Shire – Cronulla, Bate Bay, Woolooware Bay</td>
<td>Secondary treated chlorinated effluent discharged via a deep ocean outfall. (600 000 persons serviced; outfall length 2200m)</td>
<td>An options paper has been prepared for the Sutherland Shire (1995) as part of the ‘Choices For Clean Waterways’ Sydney Water Corporation community consultation process. There is a multimillion upgrade of wastewater systems in the Sutherland Shire which includes the Cronulla WWTP.</td>
<td>Sydney Water Corporation (1995)</td>
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</table>
The villages of Bundeena and Mainbar are currently unsewered, and may be connected to the Cronulla WWTP system, which would increases the wastewater stream by a further 2%.

Significant ecosystems within the Sutherland Shire include the Georges River and Botany Bay which are used for recreational and commercial fishing. Significant natural wetland habitats include: Quibray Bay, Weeney Bay, Towra Point and Woolooware Bay. The Cronulla WWTP and outfall are on the Kurnell Peninsula which is a popular recreational area for the village of Kurnell, Botany Bay National Park and Cronulla.

Options for future disposal/re-use of wastewater will be evaluated as part of the Environmental Impact Assessment in keeping with the protection of human health and ecosystem criteria set by the Environment Protection Authority (NSW). All options will be assessed for benefits, costs and risks to human health and the environment.

An Environmental Impact Statement was due for completion in August, 1995. Following a further round of community consultation the determination report will be written in conjunction with regulators.

Monitoring by ‘Beachwatch’ has indicated that water quality at Cronulla Beach has been improving since Sydney Water Corporation improved screening and sedimentation processes at Cronulla WWTP between 1992 and 1993 (cost $7m). The Bate Bay Study identified the Potter Point Outfall (operational since October 1990) from the Cronulla WWTP as the major contributor to water quality problems in the Bay.

Options for future disposal/re-use options need to be in keeping with the Sydney Water Corporation’s Operating License which include: water conservation; control of pollution at source and reuse of sewage by-products, treated effluent and sludge (biosolids) and treatment options.

Strategies identified to manage wastewater include: water conservation; controlling wastewater at source; strategies that reduce load on sewers; reuse of any remaining wastewater treated by WWTPs to be treated to standards demanded by the market and legislation and treat and discharge any remaining water to meet water quality guidelines. Re-use options were identified for: small (household) scale; new smaller WWTPs; and large scale reuse. Options for treatment and discharge were: treatment and discharge within the Shire; and outside the shire.

Three categories of options were identified: those which combine effluent reuse with treatment and discharge of leftover within the shire; those which provide only treatment and discharge within the shire and those for treatment and discharge outside the shire with possibly some reuse.
<table>
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<tr>
<th>State</th>
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<th>References</th>
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</table>
| New South Wales   | Country Towns and Catchments                  |                                                                                 | The preferred option for the Regional Effluent Management Scheme includes:  
  - reuse of treated wastewater for agricultural irrigation, woodlots and recreation  
  - a constructed wetland at Terara with wet weather discharges to the Shoalhaven River  
  - provision for including the effluent from the townships of Nowra and Bomaderry.                                                                                                                                   | Sydney Water Board (1993b)       |
|                   | Bellambi                                      | The WWTP has been upgraded as part of the ‘Clean Waterways’ Program.            |                                                                                                                                                                                                                           |                                  |
|                   | Coffs Harbour                                 |                                                                                 | 32 000 persons serviced.                                                                                                                                                                                                   |                                  |
|                   | Hunter: Newcastle/Port Stephens and Shellharbour WWTPs | A 4-year Hunter Environmental Monitoring Program being conducted by EPA (NSW), Hunter Water Corporation, MSB Hunter Ports Authority, commenced in February 1992. | Sydney rock oysters are being used to monitor, sites near outfalls at Boulder Bay, Belmont and Burswood Beach WWTPs. Organochlorines and trace metals are generally low at the site. | EPA (NSW) (1993b)                |
|                   | Lake Illawarra – Shoalhaven                  | The WWTP has been upgraded as part of the ‘Clean Waterways’ Program.            |                                                                                                                                                                                                                           | Sydney Water Board (1994c)       |
|                   | South Coast                                   | The St Georges Basin and Huskisson wastewater treatment plants treat the wastewater prior to discharge into Plantation Point, Vincentia into Jervis Bay. The system will reach its capacity by 1996. | By the year 2000 discharges to Jervis Bay will have ceased. The scheme will be divided into stages so the annual increase in rates will be a maximum of $140/year (1994 dollar values). By the end of 1995, an Environmental Impact Statement will be prepared. | The Council of the City of Shoalhaven (1994) |
|                   | Wollongong – Port Kembla                      | The WWTP has been upgraded as part of the ‘Clean Waterways’ Program.            |                                                                                                                                                                                                                           | EPA (NSW) (1993b)                |
Appendices - 7

Northern Territory

Coastal Region

Disposal of wastewaters along the coast is either to the ocean or to mangrove swamp, and comes from both small aboriginal populations and developed areas (e.g. Darwin).

Coastal waters off the Northern Territory are generally pristine except for the impact of the disposal of sewage effluent into the coastal waters off Darwin. The problem is not as extensive as coastal waterways in other capital cities of Australia due to the relatively small coastal population Of 85 000 (73 000 in Darwin). Total population for the Northern Territory is 157 000.

Effluent from small Aboriginal populations has little affect on the ocean. Effluent from Darwin is disposed of to mangroves after treatment in oxidation ponds. One outfall discharges untreated wastewater to the ocean.

Studies show the mangroves to trap nutrients, pesticides and heavy metals. Both mangroves and invertebrate populations do not appear to be affected by any nutrient enrichment. This may be due in part to strong tides and currents. It is not known what the assimilative capacity of the mangroves is.

Queensland

LGA:

Brisbane 1 250 000 EP (Equivalent Persons).
S. Albert 70 000 EP
Gold Coast 325 000 EP
Ipswich 125 000 EP
Moreton 175 000 EP
Beaudesert 12 350 EP
Logan 154 000 EP
N. Albert 42 300 EP
Caboolture 51 000 EP
Pine Rivers 85 600 EP
Redcliffe 75 000 EP
Redland 82 000 EP
Caloundra 47 000 EP
Maroochy 78 000 EP
Noosa 12 500 EP

Elevated nutrients are prevalent within sewage outfalls. Wastewater treatment facilities in SE Queensland are provided by Local Government Authorities. Most plants provide secondary treatment. Some effluent is treated to tertiary standards which incorporate nutrient removal processes. The lack of baseline data on nutrient assimilative capacities of receiving waters has hampered the development of regional or State policies regarding the need for tertiary treatment.

Most existing plants discharge to waterways or ocean. Caloundra City is undertaking work to implement some land disposal. Wastewater planning/disposal options studies have been undertaken for the Gold Coast City Council, Albert Shire Council (1970s), Caloundra City Council, Maroochy Shire Council (1990s); and Logan, Redland, Beaudesert and Albert Shires for the Logan Coomera Catchment (1993).

References

Hanley & Couriel (1992)
Zann (1995)
Regional Planning Advisory Group (1993)
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<tr>
<td>Queensland</td>
<td>Country Areas</td>
<td></td>
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<tr>
<td>Coombabah</td>
<td>70 000 persons serviced. Secondary treated chlorinated effluent is discharged at ebbtide.</td>
<td></td>
<td>WAWA (1994f)</td>
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<tr>
<td>Kawana</td>
<td>35 000 persons serviced. Secondary treated chlorinated effluent is discharged from a 1000m long outfall.</td>
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<td>WAWA (1994f)</td>
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<tr>
<td>Noosaville</td>
<td>8300 persons serviced. Secondary treated chlorinated effluent is discharged from a nearshore outfall.</td>
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<td>WAWA (1994f)</td>
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<tr>
<td>Great Barrier</td>
<td>Reef Marine Park</td>
<td>The lagoon environment of the Great Barrier Reef Marine Park (GBR) has become eutrophic, and one of the causes is the disposal of wastewater to the marine environment.</td>
<td>Sewage inputs contribute less than 10% to coastal Queensland waters. Sewage discharges account for only 2.2% and 8.1% of total nitrogen and phosphorus between Cape Tribulation and Dunk Island. Other sources of nitrogen and phosphorus include rivers, upwelling of oceans, rainfall, reefal nitrogen fixation and Trichodesmium fixation. Each year, 234 tonnes of nitrogen and 62 tonnes of phosphorus are discharged to the ocean from 3 plants in Cairns.</td>
<td>Steven and Brodie (1994)</td>
</tr>
<tr>
<td>Green Island</td>
<td>Primary treated effluent discharge has been replaced by tertiary treatment process.</td>
<td>Large increase in growth rate and area of seagrass have been reported near the bay. Ongoing monitoring of seagrass beds is continuing.</td>
<td>Brodie (1994)</td>
<td></td>
</tr>
<tr>
<td>Great Keppel</td>
<td>Secondary treated effluent is discharged via a marine outfall.</td>
<td></td>
<td>Brodie (1994)</td>
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<td>Island</td>
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<tr>
<td>Hamilton Island</td>
<td>60% of Hamilton Island’s secondary treated effluent is discharged to ocean, the remainder is used in irrigation.</td>
<td></td>
<td>Brodie (1994)</td>
<td></td>
</tr>
<tr>
<td>South Molle Resort</td>
<td>Effluent is tertiary treated before being discharged via a marine outfall.</td>
<td></td>
<td>Brodie (1994)</td>
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<tr>
<td>Queensland</td>
<td>Trinity Inlet Estuary System</td>
<td>15 000 EP) discharge into the back of the Trinity Inlet estuary system. The outfalls are in a poorly flushed area of the inlet.</td>
<td>Effluent is secondary treated prior to disposal into coastal streams or the ocean. Some of the treated effluent is re-used for irrigation of parks and gardens.</td>
<td>Brodie (1994)</td>
</tr>
<tr>
<td></td>
<td>Great Barrier Reef Coastal Towns:</td>
<td>Bundaberg, Cairns, Gladstone, Ingham, Innisfail, Mackay, Rockhampton, Townsville</td>
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<tr>
<td>South Australia</td>
<td>Adelaide: Bolivar WWTP</td>
<td>Sewage is treated by primary and secondary processes. Sludge is digested anaerobically and pumped to drying lagoons. The dewatered sludge is dried, treated and reused (see also Sludge Re-use – Appendix C). The reclaimed water is discharged to the Gulf of St. Vincent via a 12km long channel. Two pumping sumps are provided along the channel to encourage reuse. 10% of treated effluent is reused at the moment.</td>
<td>Bolivar reclaimed water exceeds the ANZECC Guidelines for Fresh and Marine Waters for Nitrogen (N), Phosphorus (P), Copper, Mercury, Nickel and Zinc and faecal coliforms. The current situation is that the HIAT Woodlot trial and more active encouragement for horticulturalists to reuse treated effluent in the Virginia Triangle is underway. Meanwhile odour emissions in the Adelaide Trunk Sewer are being reduced by oxygen and chlorine injection and the sludge lagoons have been extended. The two future options regarding disposal from Bolivar are continuation of marine discharge with improved treatment to reduce nutrient and faecal coliform level or land based disposal following enhanced treatment and management to reduce faecal coliforms and TDS.</td>
<td>Kahaalp (1994),</td>
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<td>Kinhill Engi-</td>
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<td>neers (1993)</td>
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<td>South Australian Centre for Economic Studies (1994)</td>
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<td>Camp Scott</td>
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<td>Furphy Pty Ltd  (1993)</td>
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<td>Gobbie et al.,  (1991)</td>
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<tr>
<td>South Australia</td>
<td>Christies Beach (SE Metropolitan Region)</td>
<td>The WWTP is an aerated sludge plant. The treated effluent is discharged via an outfall 330 m from shore into the Gulf of St Vincent.</td>
<td>Apart from usage at HIAT and the Virginia Vegetable Triangle (VVT) wastewater could be reused by recreational areas, industry or by groundwater injection. The cheapest costed option is to dispose to the Gulf of St Vincent via wetlands and short outfall ($65m). Deep ocean outfalls and combination of seasonal use of Gulf disposal/ VVT or total reuse at VVT have also been costed ($78m– $203m).</td>
<td>Gutteridge, Haskins and Davey (1994)</td>
</tr>
<tr>
<td></td>
<td>Glenelg WWTP</td>
<td>The majority of effluent from Glenelg is currently discharged into the Gulf of St Vincent through three outfalls some 300m offshore.</td>
<td>Options were investigated to decrease the nutrient levels, particularly of N and P to the Gulf of St Vincent. The EWS is considering the re-use/disposal options. Planning is under way for a new larger outfall to improve dispersion and replace the at capacity short outfall. The least cost and most appropriate options were determined using existing ANZECC Guidelines as well as criteria developed based on the assimilative capacity of the receiving waters. The least capital cost option is to reduce the nutrient load to Gulf of St Vincent to moderate levels. The full economic analysis was not made for income earned from the use of reclaimed water by re-use customers. A review of the options available found: • If the current ANZECC Receiving Water Guidelines apply, the least cost option involves an inshore outfall with treatment at the Glenelg plant as appropriate to meet selected criteria (i.e. partial N removal or high N and P removal).</td>
<td>Kinhill Metcalf &amp; Eddy (1994)</td>
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<td>South Australia</td>
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<td>Rural Areas:</td>
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<tr>
<td>Aldinga (Part of Willunga Basin)</td>
<td>Sewage is tankered (800 persons) to the Christies Beach sewerage system for treatment, as this has been cheaper than providing a local STP.</td>
<td>Due to expanding populations, tankering is becoming too costly. Construction of a local treatment plant with disposal scheme based on irrigation of vineyards has been proposed. $6.5 million will be required to construct the treatment plant and purchase the land to be irrigated.</td>
<td>E&amp;WS (1994b)</td>
<td></td>
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<tr>
<td>Port Augusta East</td>
<td>Port Augusta East WWTP disposes treated effluent from a tidal flat at the head of the Spencer Gulf. Nearby the ETSA disposes fly ash to the Gulf. The North Spencers Gulf region coastal ecosystems have been impacted upon as a result of sewage disposal practices.</td>
<td>The impact of the effluent in comparison to the fly ash is assumed to be minimal. An investigation of the environmental impacts is under way.</td>
<td>E&amp;WS (1994b)  Zann (1995)</td>
<td></td>
</tr>
<tr>
<td>Port Lincoln</td>
<td>Untreated sewage is discharged into Back Bay through an outfall and diffuser.</td>
<td>A new treatment plant is about to be commissioned using a decant treatment process to reduce nutrient levels in the treated effluent to 5–10mg/L total N and 5 mg/L totals P. Ongoing monitoring will determine if further treatment is necessary.</td>
<td>E&amp;WS (1994b)</td>
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<tr>
<td>Whyalla</td>
<td>Whyalla has a lagoon-based treatment system whereby the treated effluent is discharged via mangroves into Spencer’s Gulf.</td>
<td>An environmental impact assessment in under way</td>
<td>E&amp;WS (1994b)</td>
<td></td>
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<tr>
<td>Tasmania</td>
<td>Burnie</td>
<td>Elevated nutrients from sewage and agricultural run-off exists</td>
<td></td>
<td>Zann (1995)</td>
</tr>
<tr>
<td></td>
<td>Devonport</td>
<td>There are several ocean discharging plants in Tasmania. Devonport is the largest with a flow of 14.7 ML/d (only 9% of total effluent is discharged to ocean). Most ocean disposal sites undergo primary treatment (fine screening). Secondary treatment is used when discharging into bays. Most discharges are via near-shore outlets except the ocean outfall at Devonport.</td>
<td></td>
<td>DPIE (1991)</td>
</tr>
<tr>
<td>Victoria</td>
<td>Melbourne: Carrum</td>
<td>70% of Victoria’s population (3.7m) live in Melbourne or Geelong. Victoria has 2000 km of coastline, and supports the highest coastal population density in Australia. Water quality problem areas are Port Phillip Bay, Western Port Bay and the Gippsland Lakes. 1 200 000 people are serviced by the Eastern WWTP. 40% of Melbourne’s wastewaters are treated at Carrum. 99.5% of the time the Eastern Treatment Plant complied with 1993/94 EPA discharge licensing arrangements.</td>
<td></td>
<td>Zann (1995)</td>
</tr>
<tr>
<td></td>
<td>Werribee</td>
<td>2 000 000 people serviced by the WWTP. 520 ML/day (60% of Melbourne’s wastewater/day) is treated at the Western Treatment Plant. Effluent is secondary treated, chlorinated and discharged from five nearshore outfalls. About 420 ML/day is discharged. The annual volume discharged was 0.16km$^3$ in 1989. The Western Treatment Plant occupies 10851ha (6700ha used for the treatment process). Treatment comprises year-round lagooning, supplemented by irrigation in summer and grass filtration during cooler months. The plant also treats 90% of Melbourne’s industrial liquid waste.</td>
<td></td>
<td>Melbourne Water (1994) WAWA (1994f)</td>
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<tr>
<td>Victoria</td>
<td></td>
<td>During any one year the WWTP discharges: 800t of organic N; 150t of Nitrate; 40t of Nitrite; 1000t of Phosphorus; and 4000–5000t of Organic Carbon. Concentrations of metals in discharges are generally slightly in excess of ANZECC guidelines. Chromium and iron discharges have decreased in the 1980s. 99.4% of the time the Eastern Treatment Plant complied with EPA discharge licensing arrangements (1993/1994). The remaining 10% of Melbourne’s wastewater is treated at 27 local treatment plants. Of the 24 local treatment plants licensed by the EPA, 97% achieved compliance levels in 1993–94.</td>
<td>Vines (1992)</td>
<td>Vines (1992)</td>
</tr>
<tr>
<td>Melbourne</td>
<td>Country Areas: Geelong Water Board</td>
<td>The Geelong and District Water Board provides water and wastewater services to 3900km² which includes Geelong, Bellarine Peninsula and coastal and inland townships and part of the Otway Ranges. There are 14 ocean discharges along the Ocean Coast. Pollution from sewage discharges is particularly a problem at Boags Rocks.</td>
<td>Vines (1992)</td>
<td></td>
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<td></td>
<td>Anglesea</td>
<td>Compact treatment plant (0.6 ML/day) with primary treatment processes, followed by secondary treatment processes. The treated effluent is discharged beyond the shoreline.</td>
<td>Vines (1992)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Black Rock</td>
<td>The WWTP services 236 000 people, and is located between Barwon Heads and Torquay. The effluent is milliscreened, and the grit is removed prior to disposal from a 1200m long ocean outfall. The plant treats 55 ML/day. 13% of this volume is licensed as commercial and industrial wastes. This plant is to be upgraded to meet EPA Guidelines, to facilitate safe ocean disposal and future reuse of treated effluent.</td>
<td>Vines (1992)</td>
<td></td>
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| Western Australia | Beenyup        | Beenyup WWTP services 364 000 people. Effluent is secondary treated prior to discharge via two outfalls of 1600m and 1800m length. | Major findings of the Perth Coastal Waters Study are:  
- No measurable influences of treated wastewater outlets from Swanbourne/Ocean Reef on the ecology of surrounding coastal waters.  
- Treated wastewater from the Cape Peron outlet has caused minor changes.  
- There are no signs of eutrophication due to drains entering the southern part of Geographe Bay.  
A detailed monitoring program will be implemented to ensure compliance of bathing beach water quality health standards, which will include water quality measurements, biological sampling and modelling.  
The Wastewater 2040 review stated that 83.5% of metropolitan Perth’s effluent is disposed of to the ocean, while in the southwest, only 2.1% goes to the ocean. Both primary and secondary treated wastewater reaches the marine environment. The review also has found that for most coastal areas, the ocean alone is capable of assimilating projected waste water flows for 2040. However, with the push towards reuse of wastewater, it is unlikely that complete ocean disposal of Perth’s effluent will occur. | WAWA (1994f) |
| Subiaco         |                | 213 000 persons are serviced. Effluent is secondary treated and discharged from a 1000m outfall.                                   |                                                                                                                                                                                                                           | WAWA (1994f) |
| Woodman Point   |                | 400 000 persons are serviced. Effluent is primary treated prior to disposal via a 4200m outfall.                                        |                                                                                                                                                                                                                           | WAWA (1994f) |
| Perth Metropolitan Area & the South West |                | The Perth Coastal Waters Study, in conjunction with the Geographe Bay Study, is looking at the capacity of coastal waters, from Alkimos in the north to Dunsborough in the south, to assimilate the combined wastewater discharges predicted to occur by 2040. It will also establish how the marine environment has been affected by wastewater discharges thus far, and what factors will influence the assimilative capacity. It makes up part of the Water Authority’s Wastewater 2040 initiative, a review of wastewater treatment and effluent disposal strategies for the Alkimos to Dunsborough region. |                                                                                                                                                                                                                           | WAWA (1994b) WAWA (1994e) WAWA (1994f) |
### Disposal to inland waters: creeks, lakes and rivers

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<tr>
<td><strong>Australian Capital Territory</strong></td>
<td><strong>Murray–Darling Basin:</strong></td>
<td>Approx. 90 million litres of treated effluent is discharge to the Murrumbidgee each day from the Lower Molonglo sewage treatment plant.</td>
<td>The Environment Improvement Plan for Lower Molonglo has been implemented which has resulted in almost total elimination of pollution entering the Murray–Darling River System from ACT waterways. Effluent discharges are so low below license requirements, that renegotiation of the annual license to discharge has ceased. This has been an example of a successful community involvement program.</td>
<td>Consulting Environmental Engineers (1994)</td>
</tr>
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**New South Wales**  
**Catchments:** Hawkesbury – Nepean River  
Growing populations in Sydney and nearby areas have focussed both current and future developments around the Hawkesbury – Nepean River system. The area serves a population of 700,000. 125 ML/day from 21 WWTPs is discharged to the Hawkesbury–Nepean River. There are 300 point-source pollution discharges along the river, 28 being from sewage treatment facilities not owned or operated by the Sydney Water Corporation.

Diluted sewage moves southward and below the water’s surface away from Sydney’s ocean outfalls. Levels of contaminants in fish and deployed oysters along the shoreline have decreased since the deep ocean outfalls were commissioned. Water quality has been degraded over time, with the result that higher nutrient levels are encouraging more frequent outbreaks of algal blooms and aquatic weeds. Part of the Clean Waterways Program looks at the options for reducing nutrient discharges to the River.

The nutrients come from both runoff and sewerage treatment plants. Lower reaches of the river receive tertiary treated wastewater from 10% of Sydney’s population.

Algal blooms are flushed out by releases of potable quality water, thus placing greater strain on existing potable water supplies. Strategies suggested by the Board for reducing nutrients reaching the river include:
- upgrading treatment and discharge effluent to local receiving waters
- treat and transfer to catchments west of the Blue Mountains, where it would have to be reused
- maximising the reuse of treated wastewater for potable and non-potable applications
- local, small scale treatment to replace regional collection and treatment systems
- treat and transfer out of the catchment of origin, for disposal from the coast.

Dodds et al., (1993)  
Sydney Water Board (1994a)  
EPA, NSW (1993b)
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<td>New South Wales</td>
<td></td>
<td>The EPA conducted a water quality study between 1990 and 1993 of the Hawkesbury–Nepean River. Water quality improved during this time due to reduced nutrient loads from treated effluent from WWTPs discharging into the river system. The EPA has become an active member of the Hawkesbury–Nepean Catchment Management Trust. Priority activities included negotiation with the Sydney Water Board to rationalise sewage treatment and upgrade plants, community education, monitoring water quality and economic modelling. 13 WWTPs in the Hawkesbury–Nepean Catchment have been upgraded to reduce nutrient flow into the catchment. The treatment plants are located at: Castle Hill, Glenbrook, Hornsby Heights, Kellyville, North Richmond, Penrith, Picton–Thirlmere–Tahmoor, Quakers Hill, Riverstone, St Marys, West Camden, West Hornsby and Winmalee.</td>
<td>Criteria on which the above options are to be assessed include the ecological response, environmental impacts, social consequences, technical feasibility, flexibility and the costs and pricing.</td>
<td>Sydney Water Board (1994c)</td>
</tr>
<tr>
<td>Picton</td>
<td></td>
<td>A proposed sewage treatment plant is being developed to service the towns of Picton, Tahmoor and Thirlmere. By 2003 outflow would be 3.3 ML/day and by 2012 (Stage 2) there would be 4.8 ML/day of higher quality effluent discharged to the river.</td>
<td>Using the SALMON-Q model predictions indicate that in periods of prolonged dry weather Total N would exceed guidelines in 2003 and Total N and P by 2012.</td>
<td>Gutteridge, Haskins &amp; Davey (1992)</td>
</tr>
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<td>Murray–Darling Catchment</td>
<td></td>
<td>Treated effluent from 65% of the population (340 000 people) is discharged from 69 treatment plants to the rivers in the catchment. Discharges occur from the following number of treatment plants by centres of population (1992 information): 61 (pop up to 10 000); 2 (pop 10–20 000); 4 (pop 20–30 000); 2 (pop &gt;30 000).</td>
<td></td>
<td>Gutteridge, Haskins &amp; Davey (1992)</td>
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<td>New South Wales</td>
<td>Albury</td>
<td>The plant has a capacity of 56,000 EP, and uses the activated sludge treatment method. The sludge is disposed of to a secure landfill. The treated effluent is discharged to the Murray river following chlorination and detention for 32 days in maturation lagoons.</td>
<td>Phosphorus discharges have been reduced from 100 kg/day in 1985 to 35–40 kg/day. Additional nutrient reduction facilities were about to be installed in 1993. A new plant at Nursery Valley, 5 km NW of the city will be completed by 1998, incorporating the best available economically achievable technology. An option for part river/trial wetlands/land disposal was being considered in 1993/4.</td>
<td>EPA, NSW (1993b)</td>
</tr>
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<td>Namoi Catchment</td>
<td></td>
<td>Toxic algal blooms have been experienced in reservoirs, weir pools and sections of the river in the valley.</td>
<td>Sewage treatment plants are being upgraded and reuse schemes to dispose onto land or for agricultural irrigation are being adopted</td>
<td>EPA, NSW (1993b)</td>
</tr>
<tr>
<td>Bellinger River</td>
<td></td>
<td>The Urunga Wastewater Treatment Plant has installed nutrient removal facilities.</td>
<td>Water quality is being investigated</td>
<td>EPA, NSW (1993b)</td>
</tr>
<tr>
<td>Brunswick River</td>
<td></td>
<td>Elevated nutrient levels were measured downstream of the Brunswick Heads Wastewater Treatment Plant, however recreational activity and fisheries were not affected.</td>
<td></td>
<td>EPA, NSW (1993b)</td>
</tr>
<tr>
<td>North Coastal Rivers:</td>
<td>Hastings River</td>
<td>Discharge of treated effluent into the Yeppin and Kooloonbung creeks, tributaries of the Hastings River, resulted in poor localised water quality. The overall river health was not affected.</td>
<td></td>
<td>EPA, NSW (1993b)</td>
</tr>
<tr>
<td></td>
<td>Richmond and Wilson Rivers</td>
<td>Nutrient levels are high downstream from the towns of Lismore, Casino, Kyogle and Coraki. In the assimilation zones noxious weed and toxic algal blooms are experienced during periods of low river flows</td>
<td></td>
<td>EPA, NSW (1993b)</td>
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<td>State</td>
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<td>Project Details</td>
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<tr>
<td>Queensland</td>
<td>Brisbane</td>
<td>Secondary treated wastewater is discharged into the reach of a river system (the Brisbane River), which then flows out to Moreton Bay. The Brisbane City Council initiated a joint study with the Department of Environment and Heritage examining the available scientific and environmental data on water quality and community uses of the Brisbane River and Moreton Bay.</td>
<td>A number of heavy metals exist in Brisbane’s domestic sewage, including copper and zinc, as well as pesticides. Industry trade wastes are also accepted into the sewer if the treatment plants have the capacity to treat them. The desired dilution factor for wastewater disposed of into the river system (1000:1) is not often achieved, a result of the design of the submerged shoreline outfalls not having specially designed diffusers. During the 1980s the water quality of both Brisbane River and Moreton Bay improved in terms of BOD and dissolved oxygen levels, but nutrient levels have risen, causing three ‘red tide’ incidents since 1979.</td>
<td>Lever (1993)</td>
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<tr>
<td></td>
<td>Murray–Darling Basin</td>
<td>Effluent from 12 of the 29 plants in the catchment are disposed to the rivers. Total treated effluent to the Murray–Darling River in Queensland is 9000 ML/day. Toowoomba is the major contributor (pop 79000). The other treatment plants are: Dalby (pop 8300); four (pop 3–5000); five (pop 200–1100) and one (pop 200).</td>
<td>The Toowoomba Sewerage Strategy has just been completed. The strategy has examined options to reduce nutrient flows to the Gowrie Creek; dedicated land disposal option and the possibility of reuse via agricultural, industrial, dual reticulation, urban irrigation, aquifer recharge and potable reuse options. During phase 2 of the process a biological nutrient removal treatment plant for (6000 EP) will be constructed.</td>
<td>Gardner, Bryan, Hu, Gordon, Beavers (1993)</td>
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<td>State</td>
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<tr>
<td>South Australia</td>
<td>Adelaide: Port Adelaide</td>
<td>The sewage is quite saline due to infiltration of saline groundwater. The sewage is treated by the activated sludge method. The sludge is sent to Bolivar integrated sludge management facility. The treated effluent discharges to the head of the Port River near the Bower Road Embankment. Treated effluent from the Port Adelaide WWTP impacts on the Port Adelaide River estuary and the surrounding coastal waters.</td>
<td>Future options under investigation include: continued discharge to the Port River; a new outfall to the Gulf of St Vincent; combined outfall at Glenelg; diverting Port Adelaide sewage or disposing to land via industrial reuse, irrigation, wetlands or groundwater recharge. Upgrading the level of treatment to moderately whilst still discharging to the Port River involves the least capital, operational and maintenance costs.</td>
<td>Gutteridge, Haskins &amp; Davey (1993a)</td>
</tr>
<tr>
<td>Rural Areas:</td>
<td>Angaston</td>
<td>A submersible mixer had been installed to reduce the likelihood of algal blooms by mixing the effluent with river water.</td>
<td>Land based disposal to agricultural irrigation is the future preferred option based upon economic and environmental considerations. However, the Angaston WWTP also treats waters from the Boral anodising factory (40% of waste stream volume) which is a major contributor of salts, metals and sodium. The Boral wastewater stream would need to be treated separately or concentrations of salt and heavy metals would need to be reduced before the water could be used for horticultural irrigation. Estimated capital cost of the scheme would be $600 000.</td>
<td>E&amp;WS (1994b)</td>
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<tr>
<td>Murray Darling Basin: Bird in Hand</td>
<td></td>
<td>The WWTP serves the towns of Lobethal and Woodside and the treated wastewater is discharged into the Dawesley Creek, a tributary of the Bremer River which flows into Lake Alexandrina.</td>
<td>Future options include a total land based disposal or development of an irrigated woodlot, with discharge to the creek during non-irrigation periods. The woodlot option was the least expensive at $325 000. An interim license to discharge was granted in August 1993, pending the future operational strategy.</td>
<td>E&amp;WS (1994b)</td>
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<td>State</td>
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<tr>
<td>South Australia</td>
<td>Gumeracha</td>
<td>Chlorinated treated wastewater from the WWTP is discharged into the River Torrens, which constitutes 0.66% total N and 1.96% total P of the total nutrient loss of the river upstream of the Gumeracha weir.</td>
<td>The cheapest land based wastewater re-use options were irrigation onto an established vineyard or pine plantation (capital cost est. $200 000). These options were cheaper than an increased level of treatment and continued discharge to the Torrens River.</td>
<td>E&amp;WS (1994b)</td>
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<td></td>
<td>Hahndorf</td>
<td>The WWTP has been upgraded. The treated effluent is chlorinated and discharged into Hahndorf Creek, a tributary of the Onkaparinga River which flows into the Mt. Bold Reservoir.</td>
<td>The treatment plant was commissioned in April 1994 and there is a two year creek monitoring program in place. The original EPA discharge license expired in June 1994, and the EPA was to decide whether further nutrient removal will be required before issuing the new license.</td>
<td>E&amp;WS (1994b)</td>
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<td></td>
<td>Heathfield</td>
<td>Chlorinated treated effluent is discharged from the WWTP to Heathfield Stream which joins with the Sturt River. The Sturt River flows via the Adelaide Hills and the Adelaide Plain and discharges to the Gulf of St Vincent at the mouth of the Patawalonga Basin (36.5 km from the WWTP).</td>
<td>A creek monitoring program commenced in 1994. Unsuitable terrain for land disposal has made this option economically unfeasible.</td>
<td>E&amp;WS (1994b)</td>
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<td></td>
<td>Millicent</td>
<td>Treated effluent is discharged into the SE drainage network before entering Lake Bonney.</td>
<td>The coloured effluent from the pulp mill is causes light to be limiting in Lake Bonney. Now that this effluent will be treated to reduce colour, the phosphorus from the treated municipal effluent may result in algal blooms in the future. Phosphorus removal ($60 000) and continued discharge is more cost effective than land disposal ($2 800 000).</td>
<td>E&amp;WS (1994b)</td>
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<tr>
<td>South Australia</td>
<td>Myponga</td>
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<td>Customers for re-used water are being sought.</td>
<td>E&amp;WS (1994b)</td>
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<td></td>
<td>Narracoorte</td>
<td>The WWTP discharges to a small creek which flows directly to the Myponga Water Supply Reservoir.</td>
<td>Other disposal options are still to be investigated.</td>
<td>E&amp;WS (1994b)</td>
</tr>
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<td></td>
<td>Victor Harbour</td>
<td>Treated effluent discharges into Narracoorte Creek which flows to ephemeral lakes. During winter the lakes overflows into the SE drainage network and eventually into the Coorong. Chlorinated treated effluent is discharged into the Inman River.</td>
<td>The preferred future option incorporated summer reuse for irrigation and winter discharge. The WWTP would be upgraded to incorporate nutrient reduction The options would cost between $6.2m and $10.2m to implement.</td>
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<tr>
<td>Western Australia</td>
<td>Boddington, Northam, Pearce Air Base, Pinjarra, Yunderup</td>
<td>These WWTPs were either directly or indirectly discharging water into sensitive riverine environments.</td>
<td>The EPA requested the development of management plans by 1 July 1993 and the implementation of these plans by 1 July 1994.</td>
<td>Department of Environmental Protection (WA) (1994a)</td>
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### Disposal to Wetlands

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<tr>
<th>State</th>
<th>Location</th>
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<th>Findings and Considerations</th>
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<tr>
<td>New South Wales</td>
<td>Byron Bay, Minmi (Newcastle), and the University of Western Sydney Richmond</td>
<td>Demonstration projects have been set up by the CRC for Waste Management and Pollution Control in conjunction with a local authority, university and water utility.</td>
<td>The Byron Bay project involves the Byron Bay City Council and the Public Works Department. The Minmi demonstration has been developed by the Hunter Water Corporation.</td>
<td>Fisher &amp; Stricker (1992)</td>
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<td></td>
<td>Byron Bay, Blayney and Katoomba</td>
<td>Full scale successful demonstrations have been achieved at these sites by the CRC for Waste Management and Pollution Control.</td>
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<td>Coffs Harbour</td>
<td>The Coffs Harbour City Council and CSIRO have conducted field trials testing high rate (vertical flow) wetlands using wastewater from the Coffs Harbour Sewerage Treatment Works.</td>
<td>The trial will define optimum criteria for the design and construction of wetlands, applicable to different capacities and functions. Appropriate management practices for operation will also be defined, such as optimum harvest intervals.</td>
<td>Millin &amp; Heritage (1992)</td>
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<td></td>
<td>Hazelbrook Creek, Fitzgerald Creek, Blue Mountains</td>
<td>Treatment plants were decommissioned and sewage was transferred to the Winmalee WWTP for treatment. In all, 7 WWTPs in the Blue Mountains area will be decommissioned. Four plants have been decommissioned as of June 1994. A 39 km long tunnel in the Blue Mountains will redirect sewage to the new WWTP at Winmalee. The project is due for completion in 1997, will improve water quality in the Blue Mountains and connect 6000 properties to the sewer that previously used septic tank systems.</td>
<td>Reductions of nutrients and faecal coliforms downstream of where the WWTPs were.</td>
<td>Sydney Water Board (1994b)</td>
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<td></td>
<td>North Katoomba, Blue Mountains</td>
<td>A four cell wetland system was built to treat secondary treated wastewater from the North Katoomba STP in the Blue Mountains. A combination of low and high rate wetland designs have been used.</td>
<td>A 3-year monitoring program was scheduled to start in February 1992, however preliminary visual analysis suggested that the high rate wetland produced better quality effluent.</td>
<td>Fisher &amp; Stricker (1992)</td>
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<tr>
<td>New South Wales</td>
<td>Rouse Hill Development Area</td>
<td>Artificial wetlands, covering some 60 ha, will be constructed to polish effluent from an advanced STP. The wetlands will be built as ponds along existing streams, using a combination of high and low rate wetland designs. Riffle zones, shallow stony-bedded rapids where fast moving water and effluent becomes oxygenated, will also be incorporated into the design.</td>
<td>Nutrients in the wastewater will be absorbed by reeds and other vegetation. The riffle zones encourages filamentous algae, fungi, bacteria and other aquatic organisms attached to the stones to further absorb nutrients from the wastewater.</td>
<td>Fisher &amp; Stricker (1992)</td>
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<td>The Treatment plant was opened in April, 1994. The Kellyville WWTP was decommissioned and sewage was diverted to Rouse Hill.</td>
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<td>Rouse Hill Development Area and You (1993)</td>
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<td>Sydney Water board (1994b)</td>
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<td>Queensland</td>
<td>Livingstone Shire Council</td>
<td>As of 1994, there are 9 completed pilot constructed wetlands and 1 pilot wetland under construction for sewage treatment in Queensland. The ventures were joint between local government and the Queensland Department of Primary Industries.</td>
<td>The project focuses on improving the quality of local government effluents in an area extending from Mosman to Blackall to Goondiwindi. Local government authorities are responsible for the construction and operation of the wetlands. The drought over the past four years has been a stimulus for the adoption of effluent re-use irrigation schemes. Inflow and outflow is monitored.</td>
<td>QDPI (1994b)</td>
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<td>An artificial wetland treatment system was established at Emu Park treatment plant. Reduced nutrients, suspended solids and BOD have been reported.</td>
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<td>Queensland Dept Environment &amp; Heritage (1994)</td>
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<tr>
<td>Victoria</td>
<td>Broadmeadows, Melbourne</td>
<td>The Shankland Creek Water Quality Improvement Project constructed a 12 million litre wetland to establish a natural water treatment system using aquatic plants.</td>
<td></td>
<td>Melbourne Water (1994)</td>
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## Disposal to land

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<tr>
<th>State</th>
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<th>Project Details</th>
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<tbody>
<tr>
<td>New South Wales</td>
<td>Tamworth</td>
<td>Secondary treated effluent is disposed of via the land infiltration method.</td>
<td>WAWA (1994f)</td>
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<tr>
<td></td>
<td>Murray Darling Basin</td>
<td>35% of treated effluent in the NSW portion of the Murray–Darling Catchment is disposed to land (derived value based on disposal to stream – data needs further research).</td>
<td>Gutteridge, Haskins &amp; Davey (1992)</td>
<td></td>
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<tr>
<td>Northern Territory</td>
<td>Katherine</td>
<td>Tertiary treated effluent is evaporated from holding ponds.</td>
<td>WAWA (1994f)</td>
<td></td>
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<tr>
<td>Queensland</td>
<td>Noosaville</td>
<td>The effluent is treated to secondary level using biological filtration before disposal to dunes.</td>
<td>Queensland Dept Environment &amp; Heritage (1994)</td>
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<td></td>
<td>Heron Island</td>
<td>Secondary treatment of effluent followed by subsoil injection.</td>
<td>Brodie (1994)</td>
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<td></td>
<td>Orpheus Island</td>
<td>Septic tank disposal</td>
<td>Brodie (1994)</td>
<td></td>
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<td>State</td>
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<tr>
<td>Queensland</td>
<td>Murray–Darling Basin</td>
<td>Townships in the Murray–Darling Basin that dispose to land: Warwick (pop 9400); Roma (pop 6100); 1 (pop 3–5000); 6 (pop 1–3000); 4 (pop 200–1100); 4 (pop 200).</td>
<td></td>
<td>Gutteridge, Haskins &amp; Davey (1992)</td>
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<td>South Australia</td>
<td>Murray–Darling Basin</td>
<td>See re-use by irrigation for agriculture and recreation.</td>
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<tr>
<td>Victoria</td>
<td>Murray Darling Basin</td>
<td>36 of the 53 WWTPs that dispose of treated wastewater into the Murray may also dispose to land. Discharge to streams occur mainly in winter. Larger towns practicing partial land disposal are: Bendigo (pop 61400); Mildura (16300); Shepparton (28000); Wangaratta (16500); and Wodongo (23000). Mildura plant disposes to land only.</td>
<td>Murray–Darling Basin Commission (1992)</td>
<td></td>
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<tr>
<td>Western Australia</td>
<td>Kwinana, Yanchep, Bullsbrook, Port Mandurah No. 1, Kennedy, Two Rocks</td>
<td>Effluent from the treatment plants is disposed of by land infiltration, with water moving down to the ground-water. The typical disposal system involves a series of ponds storing effluent for a nearby disposal site.</td>
<td>The effects of land disposal are more easily measured from the surface. In the case of infiltration, it has the added benefit of both recharging the groundwater systems and reducing the use of scheme water supplies.</td>
<td>WAWA (1994e)</td>
</tr>
<tr>
<td></td>
<td>Eaton, Capel, Busselton No.1, Dunsborough</td>
<td>Stabilisation ponds are used to product a secondary treated effluent which is discharged on the ground.</td>
<td>Land disposal has higher infrastructure and treatment costs. These plants treat wastewater to either a secondary level, or use extended aeration methods.</td>
<td>WAWA (1994f)</td>
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<td></td>
<td>Mandurah No.1, East Busselton, Halls Head, Australind</td>
<td>Extended aeration plants are used prior to disposal onto ground. While surface monitoring presents no problems, monitoring of groundwater quality is more difficult</td>
<td>Pollution and contamination of the land and groundwater can have significant environmental and health effects.</td>
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<td>Bunbury No.1 and No.2 WWTP</td>
<td>Trickling filters are used. Bunbury No.1 discharges via a short ocean outfall at Rock Groyne. In Jan, 1996 this will be decommissioned. Effluent flow will be diverted to Bunbury No.2 where effluent is discharged to land.</td>
<td>Land requirements are high, needed for disposal as well as storage ponds for periods when the land is saturated, and a buffer distance is required to overcome odour problems.</td>
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APPENDIX C

TABLE OF WASTEWATER RE-USE PRACTICES
IN AUSTRALIA, WITH SOME INTERNATIONAL EXAMPLES

| (a) | Re-use of Wastewater for Irrigation to Primary Production – Australia |
| (b) | Re-use of Wastewater for Irrigation to Primary Production – International |
| (c) | Irrigation for Landscape and Recreation – Australia |
| (d) | Irrigation for Landscape and Recreation – International |
| (e) | Non-potable Re-use – Australia |
| (f) | Non-potable Re-use – International |
| (g) | Potable Re-use – International |
| (h) | Wastewater Sludge Re-use – Australia |
| (i) | Wastewater Sludge Re-use – International |
| (j) | Industrial Wastewater Re-use – Australia |
| (k) | Industrial Wastewater Re-use – International |
| (l) | Re-use of Wastewater for Groundwater Recharge – Australia |
| (m) | Reuse of Wastewater for Groundwater Recharge – International |
## Australian (and International) Wastewater Re-use Practices:
**Reuse of Wastewater for Irrigation to Primary Production – Australia**

<table>
<thead>
<tr>
<th>Category</th>
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<tr>
<td>Pasture</td>
<td>New South Wales</td>
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<td>The City Council has a farm on the banks of the Wollondilly River, where pasture and lucerne is grown to feed beef cattle and produce quality hay. Effluent from local treatment plants is used to irrigate the crops.</td>
<td>The supply of effluent is shared with two adjacent landholders, the Council’s proportion increasing in winter when the demand by landholders falls. GCC is also developing silviculture trials with tree species adaptable to the Goulburn climate.</td>
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<td>Crops</td>
<td>Goulburn</td>
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<td>A pilot project is in place, evaluating the re-use of effluent on agricultural land.</td>
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<td>Richmond</td>
<td></td>
<td>A pilot project is in place, evaluating the re-use of effluent on agricultural land.</td>
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<td></td>
<td>Swansea</td>
<td>Irrigation of treated effluent for pasture, fodder production and poppy crops.</td>
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<td>Victoria:</td>
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<td>The Melton Water Authority has used its wastewater for irrigation to land since 1979. This trend, a result of EPA requirements for land disposal, has continued in the 90s, with the Council purchasing a 400 ha property, of which 200 ha was used for pasture and lucerne irrigation in 1992. By 1997, another 100 ha should also be under irrigation. 22 ha has been leased to a market gardens, growing artichokes for the European market and broccoli for the domestic.</td>
<td>Local criteria have been developed for determining the suitability of an irrigation project. When selecting a site, the quality of the wastewater, soil type and profile, topography and its proximity to the water supply, the water table and the overall climate all need to be considered and matched to ensure sustainability of the project. Once the site has been chosen, selection of the appropriate agricultural enterprise, irrigation system design and management plan can be completed.</td>
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<td>Melton</td>
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<td>Shepparton</td>
<td>A trial has been established to determine the fate of nutrients supplied in recycled wastewater to irrigate pastures. Treated effluent from the Shepparton Water Board has been used for the trial, and is compared with channel water (from an open Rural Water channel) irrigation and dryland pasture.</td>
<td>Results after one year indicated that pasture irrigated with the wastewater produced 60% more plant matter, the topsoil having higher concentrations of nutrients, higher pH, cation exchange capacity, Ca:Mg ratio, total soluble salts and electrical conductivity. Nutrient concentrations in plant tissue were similarly higher with effluent irrigation, and surface soil structure was better.</td>
<td>Parameswaran (1993)</td>
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<td>Category</td>
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<td>Turf Farms</td>
<td>Western Australia:</td>
<td>A turf farm is negotiating for the use of treated wastewater for irrigation purposes.</td>
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<td>WAWA (1994b)</td>
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<td>Yunderup</td>
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<td>Vegetable and commercial crops</td>
<td>New South Wales: Dubbo</td>
<td>The effluent will be reused for irrigation of commercial crops on land adjacent to the two treatment plants, with some water available to irrigate town parks and reserves.</td>
<td>The City has adopted a reuse strategy for wastewater, aimed at eliminating disposal of effluent to the Macquarie River by the end of 1994.</td>
<td>Gutteridge, Haskins &amp; Davey CH2M HILL (1992)</td>
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<td>Griffith</td>
<td>The new FILTER (Filtration plus Irrigated cropping for Land Treatment and Effluent Reuse) technique developed by CSIRO involves physical loosening of the soil and chemical amelioration in the top soil layers to create and maintain soil macroporosity. Water can flow through the soil to a series of interconnected drains. Control gates regulate the rate of leaching from the drains.</td>
<td>This new technique of effluent treatment can be used to irrigate soils with restricted internal drainage on a year-round basis. Irrigation to a soil of low permeability can lead to waterlogging and crop damage. Benefits of this technique include the maintenance of watertable depth, and the stripping of nutrients from the water due to controlled flow rates through soil. Cropping on land after such irrigation allows for the removal of nutrients with harvesting.</td>
<td>CSIRO, Division of Water Resources (1994)</td>
</tr>
<tr>
<td>South Australia:</td>
<td>Virginia horticulture region,</td>
<td>Since the 1970s growers in the Virginia area have used effluent from the Bolivar Treatment Plant for growing stock fodder and food crops which are cooked or processed before they are eaten.</td>
<td>The Virginia Pipeline Scheme was developed in response to two problems. The Bolivar Sewerage Treatment Works were discharging an increasing amount of effluent to the Gulf of St Vincent, causing an excessive accumulation of nutrients. The result was a decline of the sea grass meadows and mangrove forests and environmental problems in the Port Adelaide River Estuary. Concurrently, growers in the Virginia area were experiencing water shortages due to over-exploitation of local aquifers. Currently only 10% of the reclaimed water is re-used.</td>
<td>Kahaalp (1994)</td>
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<td>Adelaide</td>
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<td>Kinhill Engineers (1993)</td>
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<td>South Australian Centre for Economic Studies (1994)</td>
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<td>Camp Scott Furphy Pty Ltd (1993)</td>
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<tr>
<td>Vegetables and commercial crops</td>
<td>South Australia:</td>
<td>There are plans to upgrade the Virginia Pipeline, so that ocean discharges will</td>
<td>There are plans to upgrade the Virginia Pipeline, so that ocean discharges will eventually cease, with the remaining effluent to be stored for use in summer. Capital cost for additional reticulation to the edge of the growers properties will be $30m. Only 200 of the 1000 growers have committed to receiving the wastewater. Advantages of adoption would be: the reduction of N and P discharges to the Gulf, thereby reducing pressure on the aquatic environment (saving $4m); increased value of the fishing industry (current value $4m); increased value of the horticultural industry ( $28m increase in production and a further $14m flow on to the wider community). The SA Health Commission sanctions the project, as long as viral contamination is controlled. The State Government is deciding on whether to progress with the project in early 1995.</td>
<td>Parameswaran</td>
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<tr>
<td></td>
<td>Virginia horticulture</td>
<td></td>
<td></td>
<td>(1993)</td>
</tr>
<tr>
<td></td>
<td>region, Adelaide</td>
<td></td>
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<tr>
<td>Victoria:</td>
<td>Werribee</td>
<td>The Victorian College of Agriculture and Horticulture and Melbourne Water</td>
<td>There were no yield reductions and few ill effects from the irrigation. Late in the season some stem rot appeared, and further studies will determine if the fungus causing the rot is effected by the wastewater. Despite this, crops responded well to irrigation, and further trials may lead to establishment of commercial crops of Jerusalem artichokes that in turn help reduce the quantity of effluent released to inland waterways.</td>
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<td></td>
<td></td>
<td>investigated the potential for growing Jerusalem artichokes with treated waste-</td>
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<td>water.</td>
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Appendices-30
<table>
<thead>
<tr>
<th>Category</th>
<th>Location</th>
<th>Project Details</th>
<th>Considerations/Findings</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodlots</td>
<td>New South Wales: Australian Newsprint Mill, Albury</td>
<td>Primary treated effluent is used to irrigate a crop of <em>Pinus radiata</em>, the raw material for its paper manufacture.</td>
<td>Effluent from the paper plant differs from municipal wastewaters. There are lower concentrations of N and P, and high BOD.</td>
<td>Borough and Johnson (1990)</td>
</tr>
<tr>
<td></td>
<td>Lower Hunter Valley</td>
<td>5000 <em>Eucalyptus grandis</em> were planted in 1992 to remove additional phosphorus loadings resulting from the increased capacity of the Branxton Treatment Works.</td>
<td>The economic benefits of the scheme include timber production and the reduced costs associated with not treating effluent to tertiary standards.</td>
<td>Ling and Dennis (1992)</td>
</tr>
<tr>
<td></td>
<td>Wagga Wagga</td>
<td>$500 000 has been invested in the Effluent Plantation Project which trials the use of wastewater for irrigation of woodlots in Wagga Wagga. The project commenced in 1991 with the planting of 7600 native and exotic trees, and uses wastewater from the City Council's treatment works, the nearby Royal Australian Air Force base and Forest Hill residents.</td>
<td>The NSW State Pollution Control Commission tightened nutrient discharge standards for effluent from inland wastewater treatment plants. Woodlots have been established by the Hunter Water Commission to utilise the excess phosphorus from the secondary treated effluent.</td>
<td>Bennett (1993)</td>
</tr>
</tbody>
</table>

Information about the physical and chemical soil properties, effluent characteristics, climatic data, expected growth/water use, and depth/location of a potable water table is needed to assess the feasibility of a project site. Changes in soil characteristics, and the fate of heavy metals and toxins, determines the long-term viability of effluent irrigation.

Trees irrigated with effluent grow twice as fast as those without, but may be of a lesser quality.

The rotation period and time to harvest will need to be short to remove nutrients from the site.
<table>
<thead>
<tr>
<th>Category</th>
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</thead>
<tbody>
<tr>
<td>Woodlots</td>
<td>South Australia: Berri Winery, Glossop</td>
<td>Since 1986, the wastewaters are settled and screened before being pumped 5 km onto the river plains to a 40 000 stand of <em>Eucalyptus camaldulensis</em>. At the Berri Estate, wastewaters were being held in a storage and evaporative lagoon at the rear of the site.</td>
<td>The SA State Government required Berri Estate in 1984 to establish alternative means of disposal of distillery and winery wastewaters. When the trees are 10 years old a major crowning will be required. After a further 10 years, the trees will be replaced with new seedlings.</td>
<td>Kennedy (1992)</td>
</tr>
<tr>
<td>Hardwood Irrigated Afforestation Trial (HIAT) Bolivar, Adelaide</td>
<td>The HIAT Trial was established in 1992 to determine the most suitable tree species and best plantation management practices.</td>
<td>The shallow saline groundwater table was a site constraint, limiting the tree species selected for the site. Results to date show high productivity and growth rates, especially for <em>Eucalyptus globulus</em> and <em>E. grandis</em> species. The trees are capable of accumulating nutrients from the wastewater. A number of environmental changes have been noted. The treated wastewater seems to be causing cyclic reversals in soil chemical properties between sodic (sodium rich) and saline sodic conditions in the root zone, however on a yearly basis the sodic nature is retained. The leaching of certain key nutrients has also occurred.</td>
<td>Hanna et al., (1992) Hanna et al., (1994)</td>
<td></td>
</tr>
<tr>
<td>Mount Burr Nangwarrry</td>
<td>The WWTP discharges into a depression/wetland in the pine plantation.</td>
<td>The preferred option is to supply drip irrigation for 12 months of the year to the pine plantation (estimated cost $75 700 Mount Burr; Nangwarrry $103 400).</td>
<td>E&amp;WS (1994)</td>
<td></td>
</tr>
<tr>
<td>Victoria: Melbourne</td>
<td>The Longwarry Wastewater Treatment Plant in SE Melbourne, treats 0.5ML/day which is irrigated onto land surrounding the plant.</td>
<td></td>
<td>Melbourne Water (1994)</td>
<td></td>
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<tr>
<td>Mildura</td>
<td>The Sunraysia Water Board has established a woodlot which utilises treated effluent. The area under irrigation is soon to grow from 100 to 300 ha.</td>
<td></td>
<td>Eden (1994)</td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td>Location</td>
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<td>Considerations/Findings</td>
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<tr>
<td>Woodlots</td>
<td>Portarlington, Winchelsea</td>
<td>The Geelong and District Water Board has around 60 ha of land which will support 150 000 to 160 000 trees irrigated with treated effluent from the Winchelsea (0.3 ML/day) and Portarlington (1.3 ML/day) Regional Wastewater Treatment Plants.</td>
<td>The main problems with the use of secondary treated effluent are: heavy clay soils used for irrigation with wastewater; high sodium content of wastewater; high groundwater tables and nutrient applications that can cause accessions to wastewater tables.</td>
<td>Semianiw (1990) Vines (1992)</td>
</tr>
<tr>
<td></td>
<td>Tatura</td>
<td>The Agriculture Victoria project is being conducted in conjunction with Water Authorities and some industries in Northern Victoria. A research project entitled, ‘The Fate of Nutrients Supplied in Wastewater Used to Irrigate Pasture’ is being conducted</td>
<td></td>
<td>Keary et al., (1995)</td>
</tr>
<tr>
<td>Western Australia:</td>
<td>Albany</td>
<td>Treated wastewater is pumped to holding ponds on the land treatment site, and then distributed over a 14 ha overland flow pasture area, to remove 50% of the nitrogen. Runoff from the pasture is diverted to a storage dam, until used to irrigate 300 ha of <em>Eucalyptus globulus</em>.</td>
<td>Prior to establishment of the woodlot, one of four treatment plants in Albany discharged to King George Sound, raising pollution levels. The cost of the land treatment system was $2.9m. The annual operating cost has been estimated at $224 000 in 1994/5, increasing to $283 000 by 2020. Estimated income from harvesting the woodlots is $470 000 – $780 000 pa over the next 25 years. Harvesting will commence in 1997/8 of 50 ha pa, producing 12 000m$^3$ of timber on a 6-year rotation.</td>
<td>Abbott (1993)</td>
</tr>
<tr>
<td>Unspecified agricultural use</td>
<td>New South Wales: Richmond</td>
<td>A pilot project has commenced which evaluates the re-use of effluent on agricultural land.</td>
<td></td>
<td>Sydney Water Board (1993b)</td>
</tr>
</tbody>
</table>
### Reuse of Wastewater for Irrigation to Primary Production – International

<table>
<thead>
<tr>
<th>Location</th>
<th>Project Details</th>
<th>Findings &amp; Considerations</th>
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</thead>
<tbody>
<tr>
<td>Orlando, Florida USA</td>
<td>The Water Conserv II Project is the first example of treated wastewater being used to irrigate crops for human consumption in Florida. It began in 1986/87 and continues today, with high quality treated wastewater supplied by the City of Orlando and Orange County pumped to a distribution centre for storage. About two-thirds of this water is supplied to citrus tree growers, the remaining third disposed of to land by rapid infiltration basins. Some irrigation water is used on cold nights, sprayed on the trees to prevent frost damage. The project operates under a 20-year contract between growers and the city and county binding to the landowner. Under this contract the city provides a guaranteed amount of free, uncontaminated, reclaimed water. Growers can terminate this contract if the water has a detrimental impact on the crop. Water allotment can also be increased or refused on a weekly basis for 4 weeks per year, but for no more than two consecutive weeks. A buy-out clause is also provided.</td>
<td>This project has worked in conjunction with others (see international groundwater table) to reduce the demand placed on the Florida aquifer. Water Conserv II has also decreased disposal costs and met a zero discharge mandate. The water meets US Environmental Protection Agency Class I reliability requirements, ensuring a clear, odourless, virus-free product that is safe for human contact and does not contaminate groundwater. A number of studies have been completed over the project's life to assess the impact of the wastewater on the trees and their environment. There have been no obvious problems, but rather many obvious benefits. Yields are estimated to have increased by 10–30%, with growth rates of two cultivars of young oranges in one study increasing by 225% and 443%. The increases in growth and growth rate are associated with greater canopy growths. Higher concentrations of nitrogen, phosphorus and sodium have been found in the leaves of effluent irrigated citrus trees, but at levels within the acceptable range. Soil analyses of the entire soil profile have shown higher levels of nitrogen and phosphorus, while potassium, calcium, magnesium and sodium levels vary annually. Soil moisture has also been higher, with over irrigation in the early days of the project causing reduced sugar contents in the fruit. This was amended with better irrigation management.</td>
<td>Jackson &amp; Cross (1993)</td>
<td>Southern California where 200 treatment plants supply 1000 re-use areas. 1000 million ML/day is reused throughout California on agricultural irrigation, landscape irrigation, groundwater recharge and industrial reuse (WAWA 1994f). Tuolumne County Water District, Sonora California binding contracts for ranchers to take water for 20–40 years to irrigate their properties (WAWA 1994f). Adamsville, Tennessee USA Arizona &amp; Florida, USA (Rose &amp; Gerba, 1991) Jezreel Valley, Israel (Teltsch et al., 1992) Near East Region (excluding Israel) (Arar, 1991) Gabal el Asfar, Egypt Sicily, Italy</td>
</tr>
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## Irrigation for Landscape and Recreation – Australian

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<tr>
<th>State/Territory</th>
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<th>Project Details</th>
<th>Reference</th>
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<tbody>
<tr>
<td><strong>Australian Capital Territory</strong></td>
<td>Belconnen</td>
<td>Reuse of effluent to irrigate grassed areas at the Belconnen Golf Course.</td>
<td>ACTEW (1994b)</td>
</tr>
<tr>
<td></td>
<td>Duntroon</td>
<td>Use of treated effluent to irrigate grassed areas at Duntroon. A long term reuse trial over the last 17 years has been conducted by CSIRO.</td>
<td>ACTEW (1994b) Consulting Environmental Engineers (1994)</td>
</tr>
<tr>
<td></td>
<td>Lower Molonglo STP</td>
<td>Irrigation of grassed areas surrounding the plant with treated effluent.</td>
<td>ACTEW (1994b)</td>
</tr>
<tr>
<td></td>
<td>Southwell Park, Lyneham</td>
<td>A pilot scheme is being trialed involving the reuse of wastewater for irrigation to recreation land. Wastewater flow is extracted from the sewer. It is locally treated using a combination of lime addition, sedimentation, biological treatment, membrane filtration and chlorination. The water is then pumped to playing fields for irrigation. Solid wastes are returned to the sewer for treatment at the Lower Molonglo Water Quality Control Centre. The advantage of the ‘sewer mining’ is that treated effluent will not have to be retransported back from the Lower Molonglo WWTP to irrigate the Park. Treated effluent may be used more in Canberra, depending on the success of this trial.</td>
<td>ACTEW (1994a)</td>
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<td>ACTEW(1994b)</td>
</tr>
<tr>
<td><strong>New South Wales</strong></td>
<td>Coffs Harbour</td>
<td>The City Council has use treated wastewater to irrigate playing fields and ovals.</td>
<td>R.Siebert, pers. comm., (2/2/1995)</td>
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<tr>
<td></td>
<td>Junee</td>
<td>Treated wastewater is used to irrigate local parks, playing fields, the golf course and the cemetery</td>
<td>Gutteridge H &amp; D – CH2M HILL (1992)</td>
</tr>
<tr>
<td></td>
<td>Lake Crackenback Village</td>
<td>Effluent generated by the Lake Crackenback Village development, next to the Perisher Ski-tube along Alpine Way, is to be reused for spray irrigation within the Lake catchment area. Four storage ponds are located on the site to hold the effluent before irrigation occurs. The effluent reuse system satisfies a condition of the development that treated effluent was not to be discharged into the nearby Little Thredbo River.</td>
<td>Gutteridge Haskins &amp; Davey – CH2M HILL (1992)</td>
</tr>
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<td></td>
<td>Scheyville</td>
<td>As part of the move to clean up the Hawkesbury–Nepean catchment, housing developments at Scheyville will reuse effluent through irrigation of open space. This becomes an alternative disposal option to otherwise discharging effluent into Longneck Lagoon, and the Hawkesbury River.</td>
<td>G H &amp; D – CH2M HILL (1992)</td>
</tr>
<tr>
<td>State/Territory</td>
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<tr>
<td>New South Wales</td>
<td>Sydney</td>
<td>Five golf courses and a race course can each use up to 1 million litres of recycled water per day in dry weather. The Sydney Water Board (1994) was investigating the potential for re-use at Port Kembla, Kurnell, the Hawkesbury–Nepean, the industrial area of Camellia and the Olympic Village site. An effluent reuse scheme incorporating a mixture of zoo effluent, saltwater and stormwater is under construction using a biological treatment, double-disinfection process. Most of the funds have been obtained via sponsorship. The reused effluent will be used for cage hose down, moat refill, toilet flushing and irrigation of the zoo’s grounds. This is the first example of primary contact re-use in NSW and the first zoo in the world to reuse wastewater treated to this level.</td>
<td>Sydney Water Board (1993) Sydney Water Board (1994)</td>
</tr>
<tr>
<td>Queensland</td>
<td>Great Barrier Reef Marine Park</td>
<td>Secondary or tertiary treated effluent is used to irrigate resort gardens and/or golf courses at the following resorts: Bedarra Bay Resort; Brampton Island; Day Dream Island; Dunk Island; Hayman Island; Hamilton Island (40% irrigation); Hitchinbrook Island Resort; Lindeman Island; Lizard Island; Nelly Bay; Community; Radisson Long Island Resort; Wappaburra Resort</td>
<td>Brodie (1994)</td>
</tr>
<tr>
<td></td>
<td>Coastal cities outside the Great Barrier Reef Marine Park:</td>
<td>Mulgrave Shire (near Cairns) Treated effluent is used to irrigate the Paradise Palms Golf Course. Thuringowa City (near Townsville) Effluent is used to irrigate golf courses and there is a policy to reuse all effluent in the future. Townsville City 50% of the effluent is used to irrigate golf courses and beef pasture land. Yeppoon All effluent is used for golf course irrigation. Yeppoon An effluent reuse scheme stores effluent from a filter plant in lagoons, which is then used to irrigate a golf course close by. Irrigation services were to extend to public open space by the foreshore and the National Parks and Wildlife reserve.</td>
<td>Brodie (1994) Brodie (1994) Brodie (1994) Gutteridge, Haskins and Davey (1992)</td>
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<tr>
<td>State/Territory</td>
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<tr>
<td>South Australia</td>
<td></td>
<td>A common practice of rural towns in Septic Tank Effluent Drainage Scheme (STEDS) areas and metropolitan STPs in South Australia is the irrigation of sports fields and golf courses with reclaimed wastewater. E.g. wastewater has been reused in Penola for at least 8 years.</td>
<td>Kayaalp (1994)</td>
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<td>Dillon, pers. comm. (24 January, 1995)</td>
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<td></td>
<td>Murray–Darling Catchment: Mannum/Port Augusta West</td>
<td>Treated effluent is used to irrigate the Mannum golf course since 1991, resulting in a zero discharge into the Murray River from the WWTP. A groundwater intrusion into the sewers has caused high salinity levels, so the treated effluent is shandled with river water prior to irrigating the golf course. Monitoring of soil and turf health is in progress. Since 1979, chlorinated treated effluent has been used to irrigate the Port Augusta Golf Course. Surplus flow is discharged to an evaporation pan.</td>
<td>E&amp;WS (1994b)</td>
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<td></td>
<td>Murray Bridge</td>
<td>Discharges to the Murray River ceased in December 1992. Treated effluent is now piped to army owned land. Three wetlands have been established and the army is using some of the wastewater for irrigation of firing ranges and to re-establish native vegetation. Seepage from the lagoons is being monitored.</td>
<td>E&amp;WS (1994b)</td>
</tr>
<tr>
<td>Tasmania</td>
<td>Riverside</td>
<td>Reuse of treated effluent on the golf course.</td>
<td>Department of Environment and Land Management (1994)</td>
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<td></td>
<td>Tea Tree Bend Sewage Treatment Plant</td>
<td>Treated effluent is reused on surrounding gardens.</td>
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<td></td>
<td>Proposed re-use</td>
<td>Glamorgan Spring Bay Council for use on the Bicheno golf course. Sorell Council proposed usage at Midway Point and Brighton Council for irrigation at Bridgewater.</td>
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<tr>
<td>State/Territory</td>
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<tr>
<td>Victoria</td>
<td>Craigieburn</td>
<td>The Craigieburn Local Treatment Plant reuses treated effluent during summer and autumn to irrigate the local golf course.</td>
<td>Lang (1994)</td>
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<td></td>
<td>Melbourne</td>
<td>Victoria has two main sewerage treatment plants: Werribee Farm and the South Eastern Purification Plant (SEPP). During 1992, Melbourne Water estimated around 1 GL of treated effluent from the SEPP was reused, primarily through irrigation to golf courses near the outfall pipeline. Several racecourses around Victoria have also been irrigated with wastewater spray. A study, commissioned by the Victoria Racing Club and Racecourse Licensing Board, showed that for the seven racecourses examined, there was a significant build up of nutrients over the period of the trials and water blending would be desirable in most cases. Sports ovals and wetlands are other reuse destinations for treated wastewater in Victoria.</td>
<td>Melbourne Water (1992)</td>
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<td></td>
<td>The Victorian State Government has encouraged the disposal of wastewater to land by irrigation where practical. Victorian regulations state that water treated to Category Two (wastewater receiving primary and secondary treatment) can be used for landscape irrigation.</td>
<td>Eden (1994)</td>
</tr>
<tr>
<td>Western</td>
<td>Karratha</td>
<td>The effluent is treated using secondary ponding techniques before being disposed of via evaporation or irrigation of recreational areas.</td>
<td>WAWA (1994f)</td>
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<tr>
<td>Australia</td>
<td>South West Region</td>
<td>Wastewater from Mandurah is treated and then used for irrigation to the local golf course. Negotiations are under way for the reuse of treated effluent to irrigate a golf course at Caddadup and an oval at Bunbury. It is possible for increasing amounts of treated wastewater to be used for irrigation of parks and recreational facilities in the south-west region. However this option can not accommodate all the effluent that is estimated for 2040. Where irrigation is both possible and appropriate, less than 50% is the average proportion of total effluent treated that would be reused under this option. For more than 50 years, 35 inland town councils in rural Western Australia have used secondary treated and disinfected effluent to irrigate parks and playing fields. Total effluent re-use for these schemes is 8 ML/d.</td>
<td>WAWA (1994b) WAWA (1994f)</td>
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Appendices-38
## (d) Irrigation for Landscape and Recreation – International

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<tr>
<th>Location</th>
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<tr>
<td>Pebble Beach, California USA</td>
<td>A $19 million irrigation project will provide seven golf courses and two recreational areas with secondary treated effluent from the Carmel Area Wastewater Reuse District (CAWD), during an 8-month irrigation-demand period. The project will bring together the CAWD, the Pebble Beach Community Services District, the Monterey Peninsula Water Management District and the Pebble Beach Company.</td>
<td>Water will be supplied at the same price as the alternative potable water supply. The Pebble Beach Company is the major fiscal sponsor of the project, while ownership and operational responsibilities belong to the CAWD and the Pebble Beach Community Services District. Five of the seven golf course will require modifications to their irrigation systems in order to meet County and State regulations for reclaimed water use.</td>
<td>Badani (1993)</td>
<td>Kawasaki City, Japan (Kuribayashi, 1991) Metropolitan Tokyo, Osaka and Tachikawa, Japan (Ohgaki &amp; Sato, 1991) ‘Sewer mining’ by Los Angeles County Sanitation District, California, USA (1994) East Bay Municipal Utility District, Oakland California recreational landscaping and industrial reuse (Williams 1995) Colorado Springs, Colorado, USA. Reused water for parks, education grounds and industries (Williams 1995) Santee &amp; Arcata, California USA (Hickinbotham, 1994) Turkey (Sarikaya &amp; Eroglu, 1993) Riyadh, Saudi Arabia 2.6ML/d for landscape irrigation (WAWA 1994f)</td>
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### (e) Non-Potable Re-use – Australia

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<tr>
<th>State/Territory</th>
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<tbody>
<tr>
<td><strong>Australian Capital Territory</strong></td>
<td>Canberra</td>
<td>Six household-level water treatment plants were installed on urban Canberra properties to treat household wastes. Collected water is stored in a holding tank, before being recycled for use in toilets and irrigation. In this case, irrigation is not subsurface, but through the existing system. This project also tested two different treatment technologies. The first was the standard Envirocycle model, the other new domestic recycling process.</td>
<td>The main emphasis of this project is the involvement of the householder in the recycling of household water. The tank of household water waiting for reuse encourages responsibility in the household, in order to operate and treat the water correctly. The tank also allows for control over irrigation, and acts as a buffer when rain renders irrigation unnecessary. The whole concept of recycling within the home makes the household aware of their own water balance. ACTEW carries out monitoring throughout the project life to ensure the quality of the water.</td>
<td>ACTEW (1994b) Consulting Environmental Engineers (1994)</td>
</tr>
<tr>
<td><strong>New South Wales</strong></td>
<td>Rouse Hill</td>
<td>The Area covers 9400 ha to the north west of Sydney, and is the next major development area to accommodate a growing population in New South Wales. There will be 70 000 new residences and a 1400 ha industrial development. Construction of houses and the supply system has begun, it may be as far away as 1997 before reclaimed water is supplied to the properties. The supply of reclaimed water from the new Rouse Hill STW (treatment to tertiary level) will include compulsory use for toilet flushing, and both potable and non-potable supplies for garden watering, making outdoor use optional. Potable water will be available during peak demand times to augment the reclaimed water supply. In addition, wetlands and riffle zones will be used to polish off treated effluent before discharging it to watercourses.</td>
<td>A condition of this development is the installation of a dual water supply in order to minimise further effluent discharges to the Hawkesbury–Nepean River system. The development will proceed in stages, with Stage 1 producing around 13 000 residential lots, requiring a facility of $285million to fund the works. On a household basis (including the cost of service reservoirs, pumping stations, distribution mains, reticulation pipework and the irrigation systems for open space for the land holder), the estimated cost of service infrastructure for dual reticulation is $1500/lot (1991 estimate). Community education is seen as a major part of ensuring the success of the Rouse Hill scheme. Newsletters will be produced regularly to keep the community informed of issues affecting them.</td>
<td>Lang (1994) Sydney Water Board (1994)</td>
</tr>
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The Rouse Hill Treatment plant was opened in April 1994. The Kellyville WWTP was decommissioned and sewage diverted to Rouse Hill.
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<tbody>
<tr>
<td>Shoalhaven Heads</td>
<td>The Shoalhaven Heads site for a pilot scheme investigating the domestic use of recycled non-potable wastewater, from which a set of guidelines acceptable to regulatory authorities and the public could be developed.</td>
<td>Project monitoring revealed that: most residents used reclaimed water only for watering gardens; high levels of support for the system despite some persistent concerns on the health risk to small children; the level of support was attributed to a free supply of reclaimed water, and the part the residents could play in preserving the availability of potable water supplies; and identical acceptance levels may not be achieved if residents are charged for using the reclaimed water. Environmental parameters were monitored over the project, including soil, groundwater and vegetation: Soil pH on land irrigated with wastewater increased from about 5.7 to 6.4, a result of the alkaline character of the water; Increases in P in the soil, similarly caused by the nature of the water; Groundwater levels and quality changed little; and the changing N to P ratio may effect native plant species in the future. The following recommendations were made:  • Monitoring is needed to assess environmental impacts  • Tests for heavy metals, toxins etc. to be carried out every 6 months, depending on site characteristics  • Soil and groundwater to be monitored every 6 months to assess changes due to reusing effluent  • Biophysical characteristics and suitability must be considered when selecting a potential reuse site  • Vegetation must be inspected regularly, and drainage flows, waterlogging, obvious diseases, deaths, abnormal growths and proliferation of weed species recorded  • Attend to odour problems quickly  • Monitor nearby waterways to determine any water quality changes</td>
<td>Lang (1994)</td>
<td></td>
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<td>State/Territory</td>
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<td>Wagga Wagga</td>
<td>Wagga City Council in conjunction with the NSW Public Works Department have planned a pilot study project involving the retrofitting of 100 houses.</td>
<td>The project scale is considered sufficient to allow adequate canvassing of community acceptance for reusing wastewater. Liaison with the Department of Health and thorough costing of the project will need to be completed before the project can proceed.</td>
<td>Lang (1994)</td>
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<td>Northern Territory</td>
<td>Black Point, Cobourg Peninsula</td>
<td>A greywater recycling trial is being conducted in the ranger houses to assist in the development of a water conservation program for remote communities.</td>
<td>Conservation Commission of the Northern Territory (1994)</td>
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<td>South Australia</td>
<td>Adelaide Area: New Haven, Lefevre Peninsula</td>
<td>At New Haven, a residential development involving the reuse of wastewater for the irrigation of an oval and gardens, and water for toilet flushing has been approved. The 2 ha site, with 67 houses, will make use of all water, including stormwater which will be mixed with treated effluent. Collected wastewater will be treated on site by a small community sewerage treatment plant. Water for drinking and on-hose contact is taken from the public mains and supplied via a separate reticulation system.</td>
<td>Construction at New Haven has commenced</td>
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<td>Andrews Farm</td>
<td>The Andrews Farm program, although smaller than New Haven with 27 new houses, will follow a similar reuse plan as the New Haven site. The trial of domestic reuse at the site, while approved by the State Government, was yet to be approved by the EPA and Department of Health by March, 1994.</td>
<td></td>
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Victoria

Melbourne

Four Melbourne households have tested the reuse of greywater for toilet flushing and garden irrigation. The sites were chosen to represent a varying range of topography, soils, houses and family size, while different combinations of greywater sources were used for different applications. The sources of greywater were kitchen sinks, bathrooms (showers and sinks) and laundries (troughs and washing machines). Together these sources account for around 45% of the average household water consumption. Of the uses, irrigation to the gardens is seasonal (restricted to a six month period) but uses 34% of household water consumed. Toilet flushing uses 20% of household water but this figure is falling with the development of more efficient dual-flush systems.

Within the distribution, the option exists for greywater to be automatically directed to the sewer whenever blockages or system malfunctions occur. Irrigation occurs by a shallow subsurface system to minimise health risks. The greywater is treated to a high quality in order to minimise build up of suspended material in the reticulation, and biological growths in toilet cisterns or its operating components. To overcome problems in the toilet cistern, coloured disinfectants are needed to reduce bacteria, and to make the water aesthetically pleasing. A disinfectant also reduces health problems associated with splashing.

Results of the project to date are as follows:
- Bathroom greywater is best suited for irrigation, while laundry greywater is more appropriate for toilet flushing.
- Design problems were encountered with the installation, or retrofitting, of treatment systems into existing houses. The preferred option is to incorporate the treatment system into the design before building.
- Identification of a suitable disinfectant for the toilet cistern is problematic, due to the differing characters of greywater for each of the householders. A suitable disinfectant must react in any solution, be cheap and easy to use, and coloured as an indicator of efficacy.
- Filtering of the greywater must produce high quality wastewater. As such, a suitable disposable filter for the treatment system must be cheap and efficient, have a high surface area and be able to be incorporated into an in-line filter.
- Storage tanks need to be vented, childproof, accessible for cleaning and comply with local health and plumbing by-laws.
- Nutrients and heavy metals can potentially contaminate irrigated soil. High zinc levels were caused by stripping of the metals in storage tanks due to treatment chemicals. High levels of sodium from household detergents can change the properties of clay soils. High P levels will cause saturation in clay soils, and leaching in sandy soils.

Christova-Boal et al. (1994)
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<tr>
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<tbody>
<tr>
<td>Western Australia</td>
<td>Palmyra</td>
<td>A block of Homeswest aged persons units were selected to test the reuse scheme. Under this scheme, bath, hand basin, shower, laundry and kitchen sink water is collected from the units, treated by a biological treatment unit on the site. The treated wastewater is chlorinated before it is stored in tanks (located in the ceiling spaces of the houses) for use in toilets, the surplus used to irrigate a dedicated area of the site. Blackwater continues to be pumped to the main sewer serving the property, with the greywater also connected to the sewer to allow for diversion of effluent if trouble occurs.</td>
<td>The domestic treatment units must be easy to check and monitor, so that an informed lay-person can deal with any minor problems that arise. Environmental Health Department regulations require that the irrigation site, containing trees and shrubs, is fenced-off from the public. Over the course of the scheme, the quality of the water, the functioning of the equipment and the health of the householders will be monitored. The project has been approved in principle, subject to maintenance, quality, and health standards being achieved.</td>
<td>Bingley (1994)</td>
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## Non-Potable Reuse – International

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<tr>
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<tbody>
<tr>
<td>Altamonte Springs, Florida USA</td>
<td>‘Project Apricot’ provides treated wastewater for all non-potable uses to every developed property in the Altamonte Springs service area. The project included retrofitting of established neighbourhoods, using trenchless construction methods to avoid disruptions, and to lower costs. The wastewater is treated to a high quality, and supplied at 40% of the price of potable water. No connection fees are charged.</td>
<td>During project development, regulatory authorities resisted change in order to protect potable water supplies. This was overcome by implementing a program to deal with the control of cross-connection areas, inspection methods and other issues raised. In the interests of safety, requirements for infrastructure and operations went beyond the state regulations and permit conditions. A public education program was initiated to cultivate community acceptance of the project. Project Apricot representatives outlined the long-term benefits at public gathering and through a number of videos.</td>
<td>Newnham (1993)</td>
<td>St Petersburg, Florida USA dual reticulation system 75 ML/d (1/3) of city’s water supply being reclaimed and used by 6000 customers to irrigate 2000 ha parks, golf courses and residential gardens. Threat to groundwater by saltwater intrusion motivated this scheme. (Hickinbotham, 1994) (WAWA 1994f)</td>
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<td>Irvine Ranch Water District, USA (Hickinbotham, 1994)</td>
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<td>Grand Canyon Village, Arizona USA. Oldest scheme in USA (1926) (Hickinbotham, 1994) (Williams, 1995)</td>
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<td>West Basin Municipal Water District (1995) consisting of three recycling schemes: West Basin (largest in USA); Century Recycled Water Project (Los Angeles County); and Rio Hondo Recycled Water Project (Williams, 1995).</td>
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<td>City State of Singapore (Ng &amp; Chia, 1991) (Chin &amp; Ong, 1992)</td>
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<td>China (Zhongxiang, 1991)</td>
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## (g) Potable Reuse – International

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<tr>
<td>Denver, Colorado USA</td>
<td>Since 1984, the Denver Potable Water Reuse Demonstration Plant has been operational. Unchlorinated secondary effluent from the metropolitan Denver Wastewater Treatment Facility. The treatment processes then applied were designed to increase reliability by incorporating multiple safety barriers. These ensure that no single process is completely responsible for the removal of any single contaminant. The project was completed in 1991. A full-scale plant has not been built because cheaper fresh water supplies are still available.</td>
<td>The project was motivated by forecasts of Denver’s demand for water resources exceeding the available supply. After considering the alternatives, potable reuse of wastewater was found to be the only option that could utilise the volume of imported water. Results from water quality and health effects testing were compared to the quality of the present drinking water supply, in addition to national and international standards for drinking water quality. For measurable constituents, such as chemical parameters and element concentrations, the water quality of the reclaimed potable water equalled or exceeded that of the existing supply. Preliminary results from health effects testing showed no health effects associated with the water.</td>
<td>Rogers &amp; Lauer (1992)</td>
<td>City of San Diego, California USA (Thompson et al., 1992) Bouwer (1992) Potable Reuse History, United States (Hamann &amp; McEwen, 1991)</td>
</tr>
<tr>
<td>El Paso, Texas USA</td>
<td>The El Paso Water Utilities Public Service Board has been treating wastewater from the Fred Hervey Water Reclamation Plant to potable quality since 1985, and using it to replenish drinking water supplies. The wastewater is treated to a secondary standard before undergoing a number of advanced processes. The water is then injected through wells to an aquifer, from where it can be accessed for municipal use.</td>
<td>The motivation for this reuse project came from the depletion of the Hueco Bolson aquifer, the source of 60% of El Paso’s water. The treatment process is subject to a strict monitoring program. Each step of the advanced treatment process is monitored, thus allowing for re-treatment of wastewater if any steps fail. Monitoring continues after the water has left the reclamation plant and reached the reservoir. The planning and construction of this project was accompanied by the formation of a citizens advisory group, which allowed for community input.</td>
<td>Bouwer (1992)</td>
<td>Windhoek, Namibia (Hickinbotham, 1994)</td>
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### Wastewater Sludge Re-use – Australia

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<tr>
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<tr>
<td>New South Wales</td>
<td>Cronulla</td>
<td>The sludge is treated and recycled into biosolid products, including soil conditioners and organic fertiliser. The main uses of the products are composting, agriculture, forestry and mine site and land rehabilitation. The ‘N-Viro Soil’ product is made from sludge generated by the North Head treatment plant. The product has been used mainly for composting and agricultural applications. Examples of sludge used on mine sites are projects at the Saxonvale and Ravensworth Mines in the Hunter Valley, and the Spring Creek Quarry in Wollondilly. In both cases the sludge is used in the re establishment of pastures and natural vegetation.</td>
<td>Sludge regulations, Health issues, Uses of the sludge (refer text)</td>
<td>Sydney Water Board (1993b), Sydney Water Board (1992c)</td>
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<td>Sludge disposal to ocean and incineration has ceased.</td>
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<td>Biosolids have been used on acidic agricultural soils: for example, where limed biosolids have been applied; at rehabilitation sites such as Springwood Golf Course; at coal mining and quarry sites; and landscaping of the third runway at Sydney Airport.</td>
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<td>Biosolids from Cronulla and Bondi are dewatered at Cronulla before being trucked to forests for application to the soil. 15 truckloads of sludge are produced per week.</td>
<td>70% of sludge is recycled and used as: compost; limed products for NSW acid soils; dried products to be used as commercial fertilisers; liquid products added to commercial fertilisers; and dewatered products high in organic matter to increase water holding capacity of soils. Bondi is about to upgrade its process to include dewatering.</td>
<td>Sydney Water Board (1994c), EPA (NSW) 1994</td>
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Appendices-47
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<tr>
<td>Queensland</td>
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<td>The Queensland Department of Health requires sludge to be stockpiled for 1 year before use. Sludge used to grow food crops are under stricter regulation to ensure that heavy metals and organic pollutants are not passed up the food chain.</td>
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<td>Beavers (1993)</td>
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<td>South Australia</td>
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<td>Sludge collected from the drying lagoons at Bolivar Sewerage Treatment Complex is stockpiled and dried. Fertiliser plants use this dry sludge, after further heat treatment to disinfect the waste, as a fertiliser base or a soil conditioner. Approval for this re-use began in the 1960s, and users of the products include carrot farmers in the Virginia region and Riverland citrus growers. Other South Australian examples include the production of bricks, 500 tonnes of sludge being supplied annually to a brick-making company. Long term mine-site rehabilitation using sludge from EWS treatment plants occurs at Brunakya, an option recommended in the 1990 EWS report. Future uses to be developed involve sludge used in woodlots and for landscaping.</td>
<td>A study undertaken by the EWS in 1990 recommended that ocean disposal of sewage sludge should be eliminated. This was to be achieved by transferring sludge from the Glenelg and Port Adelaide Sewage Treatment Works (STW) to the Bolivar STW, where sludge handling facilities would be upgraded. Reuse and disposal alternatives were also to be developed. A number of the alternatives identified in the report have since been carried out.</td>
<td>Camp Scott Furphy (1993) Gobbie (1991) Kayaalp (1994)</td>
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<tr>
<td>Tasmania</td>
<td>Glenorchy Hobart</td>
<td>Composting trials are underway at the Hobart and Glenorchy tips and experimental work with sludge injection of sewage and selected industrial wastes by private operators.</td>
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<td>Department of Environment and Land Management (1994)</td>
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### Wastewater Sludge Reuse – International

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<tr>
<th>Location</th>
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<tr>
<td><strong>New York City, USA</strong></td>
<td>The City of New York has developed a $2 billion, 3-stage, sludge-management plan that replaces ocean dumping of sewage sludge with beneficial reuse options. The agency responsible is the New York City Department of Environmental Protection (DEP). Stage I involved the design and construction of 8 dewatering facilities costing $689 million, to allow for sludge movement to intermediate processing facilities and/or reuse sites. Under Stage II, contracts were given to private companies to manage the City’s sludge until June 1998, allowing the ocean dumping of sludge to cease in 1992. The dewatered sludge is taken from New York State to a remote composting facility, used in other states for agriculture and in mined land reclamation purposes. A thermal drying plant has been constructed in the Bronx for thermal drying of the sludge to produce fertiliser pellets. The long term plan is stage III, and requires that the City become responsible for owning and operating its entire sludge management program by June 30, 1998. DEP began this plan in 1991, which involves siting and construction of sludge processing facilities that will create beneficial products, marketing strategies for products developed and the development of new process technologies. The main uses for sludge under this plan are composting in the city, chemical stabilisation for landfill cover and thermal drying to produce fertiliser pellets and soil amendments.</td>
<td>The Ocean Dumping Ban Act (ODBA) of 1988 has been the motivating factor for both the New York City DEP and other states to change their sludge disposal practices. New York City signed a consent decree with the US Environmental Protection Agency in August 1989, agreeing to the 3-stage plan. New York City was given until June 30, 1992 to end ocean dumping of sludge. The City of New York established a Citizens Advisory Council (CAC) on sludge management. Representatives on the committee came from public interest citizen organisations, environmental groups, local activists, the business community and elected officials. The CAC worked as an independent body advising the DEP of community responses towards aspects of the management plans. The Council favoured beneficial reuse options as opposed to land disposal, and encouraged the DEP in this direction. Involvement in the long term plan was limited to developing a set of criteria for the DEP to use when selecting sites for the sludge treatment facilities. With the announcement of preferred sites, the role of the CAC was to inform and educate the communities affected. While the reliance on landfills as a means of sludge disposal will decrease with implementation of the long term plan, they will remain a viable option. Long-term facilities will handle 50% of New York’s sludge by the end of 1995, the remainder by mid-1998. The DEP is investigating new applications for their sludge products. One such project is the use of sludge to fertilise corn crops whose ethanol (known as ‘gasohol’) content could be used as an alternate fuel source.</td>
<td>Austin (1992)</td>
<td>City of Los Angeles, USA (Goldstein, 1992a) Bender (1992) (Goldstein, 1992b) Clark (1992) Martinez, California, USA (Austin, 1992) Sayreville, New Jersey, USA (Austin, 1992) St. Paul, Minnesota, USA (Austin, 1992)</td>
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### Industrial Wastewater Re-use – Australia

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<th>State/Territory</th>
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<tbody>
<tr>
<td>New South Wales</td>
<td>Coffs Harbour</td>
<td>The City Council uses treated wastewater for the production of concrete, dust suppression, and rock crushing and other production processes.</td>
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<td>R. Siebert, pers com</td>
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<td>Eraring Power Station, Hunter Area</td>
<td>Secondary treated effluent from the Dora Creek Wastewater Treatment Plant is used by the Eraring Power Station. The water is filtered using a Membio membrane at the plant before being reused for: water demineralising plant feed, cooling towers make-up water and washdown, dust control and gland sealing.</td>
<td>The effluent is a great deal cheaper, at a quarter of the maximum price of potable water that would otherwise be supplied by the Sydney Water Board. The arrangement is also of benefit to the environment, as the volume of treated effluent disposed to ocean has been reduced.</td>
<td>Sydney Water Board (1992)</td>
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<td>Port Kembla</td>
<td>Since 1992, Australian Steel Mill Services Pty Ltd have been involved in an effluent re-use scheme at the BHP Port Kembla steelworks. Up to 6 million litres of treated effluent from the Wollongong Sewage Treatment Plant is pumped to the Steel Works each day, where it is used to cool molten slag into granulate. Around 2200 tonnes of granulate, used to manufacture cement, road pavement, airport runways, is produced daily.</td>
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<td>Western Australia</td>
<td>Subiaco WWTP and Beenyup WWTP</td>
<td>3.5 ML/d (5.7%) and 3.4 ML/d (5%) respectively of the WWTP’s plant water is recycled.</td>
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<td>WAWA (1994f)</td>
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<td>Woodman Point</td>
<td>A demonstration project has been established at the Kwinana Industrial Area using treated effluent from Woodman Point to demonstrate that effluent can be treated using lime softening; Memcor Microfiltration; Ecoflow cross microfiltration; vortex chemically assisted flocculation processes, so that the treated wastewater could be used by local industry in cooling towers.</td>
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<td>Boland and Edmonds (1995)</td>
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<td>Victoria</td>
<td>Commercial Polymers</td>
<td>Commercial Polymers Pty Ltd (Compol) produces polyethylene resins. Since 1974, recycling of wastewaters from the plant has occurred after treatment by an activated sludge plant. The treated wastewater supplements the water supply in the cooling tower basin, and when a high level is reached, it is diverted to irrigation of woodlots or the Compol gardens. The ‘urban forest’ was planted in 1984 with over 1000 native trees. This has grown with the addition of a further 2000 trees. A holding dam was built on the site to store irrigation water. Water captured by the dam during winter is pumped back to the plant for use in cooling towers during the summer, ensuring that the drain does not become overstocked.</td>
<td>The development of land reuse was in response to McKie &amp; Clements (1991) and discharge limits imposed by the EPA Victoria. Clements (1991) aimed at reducing wastewater disposal in the nearby Kororoit Creek. Compol had 37 ha of suitable land available for disposal purposes, and therefore followed the EPA’s preferred alternative of land disposal / reuse. The dam also supports a population of fish and birds. So far, tissue analysis of fish inhabiting the dam has shown heavy metal concentrations well below NHMRC standards. Similarly, the soil and water quality are below relevant guidelines for contaminant levels. In 1990, Compol estimated that they had saved $51 000 in potable water that would otherwise have been purchased for use in the cooling tower. In terms of operating costs, reuse within the plant was estimated at $10 000 per annum, while the alternative option of connecting the municipal sewer would equal $160 000 per annum given fixed and variable charges.</td>
<td>McKie &amp; Clements (1991)</td>
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### Industrial Wastewater Reuse – International

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| Jurong Industrial Estate, Singapore | The rapid urbanisation and industrialisation of Singapore Island has increased both the demand for potable water supplies and the incentive to reuse treated wastewater. The Jurong Industrial Estate began in the 1960s, with treated wastewater from the Ulu Pandan Sewage Treatment Works supplying the Jurong Industrial Water Works. The Water Works treat this wastewater using a variety of chlorination, aeration and filtration processes producing water of a lower quality than potable supplies that is available for industrial use. Another example of industrial reuse is the Tuas Industrial Estate. As at 1992, 42 industrial premises on both the Jurong and Tuas Estates were reusing the reclaimed water. The main water uses were for cooling (28%), general washing (8%), and process applications (paper industry 43% and the textile industry 7%). | Wastewater not reused from the Ulu Pandan Sewage Treatment Works is disposed of in the mouth of the Jurong River. The other five treatment works in Singapore similarly dispose of effluent to the surrounding seas. Conditions governing the reuse of this wastewater can be summarised as:  
• water only to be used in industries not involved in food or pharmaceuticals production  
• the industrial water is not to come in contact with potable supplies, and should be clearly differentiated on the basis of different coloured supply pipes, and  
• any installation and extension work on the pipes to be approved and carried out by the relevant bodies.  
Industries within the estates requiring higher quality supplies have installed their own treatment facilities to upgrade the water to meet such requirements. The most common treatment processes used are reverse osmosis and electrodialysis. | Ng & Chia (1991) Chin & Ong (1992) | China (Zhongxiang & Yi, 1991)  
East Bay Municipal Utility District, Oakland California. Recreational landscaping and industrial reuse (Williams 1995)  
Colorado Springs, Colorado, USA. Reused water for parks, education grounds and industries (Williams 1995)  
Russellville, Kentucky USA (Reily & Wojnar, 1992)  
Singapore Island (Chin & Ong, 1991) (Chin & Ong, 1992)  
Riyadh, Saudi Arabia 20ML/d at an oil refinery (WAWA 1994f) |
## (1) Reuse of Wastewater for Groundwater Recharge – Australia

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<tr>
<td>Victoria</td>
<td>Carrum</td>
<td>Pilot evaluating recharging effluent, using treated sewage effluent.</td>
<td></td>
<td>Lakey (1978)</td>
</tr>
<tr>
<td>South Australia</td>
<td>Adelaide</td>
<td>Experimental evaluation of aquifer recharge using treated stormwater and wastewater for subsequent recovery and second-class re-use.</td>
<td>Preliminary trials at Andrews farm have indicated that there is potential for rapid rates of injection. Further research will evaluate microbiological aspects, including clogging and pathogens.</td>
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## Reuse of Wastewater for Groundwater Recharge – International

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<tr>
<td>Orange County, California USA.</td>
<td>Water Factory 21 (WF-21) was built by the Orange County Water District (OCWD) in the early 1970s. Secondary treated wastewater from the Orange County Sanitation Districts is used by WF-21 to produce tertiary quality effluent through advanced treatment processes, including granular activated carbon (GAC) and reverse osmosis (RO). This water has consistently met all applicable state and federal drinking water standards when injected as a blend of reclaimed and deep-well water into the County groundwater basin. This replenishment of groundwater supplies augments Orange County’s domestic water supply and prevents saltwater intrusion.</td>
<td>Groundwater monitoring over the projects life has found no degradation of the groundwater quality by chemicals or microorganisms. In November 1991 the WF-21 became the first project of its kind to gain approval to inject 100% reclaimed water for groundwater recharge. This approval was given subject to certain conditions being met. The WF-21 project was driven by the high demand for groundwater resources from the Orange County basin. The falling groundwater level was allowing salt water intrusion from the Pacific Ocean. The blend of deep-well and reclaimed water was injected into the groundwater through a series of wells, creating a hydraulic barrier to the impinging salt water. The conditions of approval for the 100% reclaimed water injection were set by the State Department of Health Services (DHS). These were:  * Water standards are to be met by the injected water. Specifically, total organic carbon (TOC) and total nitrogen shall not exceed 2mg/L and 10mg/L. The OCWD will achieve this by increasing the proportion of wastewater treated by reverse osmosis (RO). The current blend using equal proportions of wastewater treated by RO and VAC combined with the deep-well water, occasionally exceeds these limits.  * The treatment process must comply with state requirements for filtered tertiary effluent.  * The construction of new domestic water supply wells is not allowed within 610m of injection wells.  * The maximum amount of injected water allowed is 1095 L/s, the maximum for reclaimed water lower at 789 L/s.  * The OCWD are responsible for conducting an approved study of the impact of injecting 100% reclaimed water into the groundwater basin. Annual reports are to be published reporting any findings. They must also submit an operating plan to the DHS for approval.</td>
<td>Conklin et al., (1995)</td>
<td>Vendee, France (Legeas et al., 1992)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Atlantis, South Africa (Wright &amp; Parsons, 1994)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Phoenix, Arizona USA (Bouwer, 1991)</td>
</tr>
</tbody>
</table>
APPENDIX D

NATIONAL EFFLUENT RE-USE

SURVEY QUESTIONNAIRE
SURVEY OF EFFLUENT DISCHARGE PRACTICES
PART 1

SUMMARY FOR ALL TREATMENT PLANTS WITHIN THE STATE,
TERRITORY OR AUTHORITY’S AREA.
(Please tick boxes where appropriate)

1. Name of Water Authority .................................................................
Address ..............................................................................................
..............................................................................................

2. Information sought in survey

Please provide summary information for all Treatment Plants under the jurisdiction of
the State, Territory or Authority in questions 3 to 9. Some views on the factors
influencing wastewater use are sought in questions 10 to 12.

Please also provide specific details of each Treatment Plant with discharge greater
than 3 Ml/day in separate questionnaire sheets headed “Survey of Effluent
Discharge Practices *Individual Treatment Plants”.

3. Numbers of Treatment Plants and their sizes (present average daily flow).
   <0.5 Ml/day ..........no.
   0.5-3 Ml/day ..........no.
   3-20 Ml/day ..........no.
   >20 Ml/day ..........no.

4. Volumes of wastewater received and anticipated.
Now ......................... Ml/ann.
By year 2000 ................. Ml/ann.
By year 2020 ................. Ml/ann.

5. Present overall levels of treatment and disinfection.

(a) Treatment
No Treatment ..........% of present volume not treated
Pre-Treatment ..........% of present vol. treated to this level only
Primary Treatment ..........% of present vol. treated to this level only
Secondary Treatment ..........% of present vol. treated to this level only
Tertiary/Adv. Treatment ..........% of present vol. treated to this level only

Total 100 %

(b) Disinfection
No disinfection ..........% of volume not disinfected
Chlorination ..........% of volume disinfected by chlorination
U/V radiation ..........% of volume disinfected by U/V radiation
Lagooning ..........% of volume disinfected by lagooning
Other means ..........% of volume disinfected by other means

Total 100 %
6. Annual volumes of effluent\(^*\)\(^*\) discharged from Plants.

<table>
<thead>
<tr>
<th></th>
<th>Now</th>
<th>By 2000</th>
<th>By 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>To land(^<em>)(^</em>) (ref. item 7)</td>
<td>.......... Ml/ann</td>
<td>.......... Ml/ann</td>
<td>.......... Ml/ann</td>
</tr>
<tr>
<td>For direct re-use (item 8)</td>
<td>.......... Ml/ann</td>
<td>.......... Ml/ann</td>
<td>.......... Ml/ann</td>
</tr>
<tr>
<td>To inland/fresh waters (item 9)</td>
<td>.......... Ml/ann</td>
<td>.......... Ml/ann</td>
<td>.......... Ml/ann</td>
</tr>
<tr>
<td>To coastal waters</td>
<td>.......... Ml/ann</td>
<td>.......... Ml/ann</td>
<td>.......... Ml/ann</td>
</tr>
<tr>
<td>Total</td>
<td>.......... Ml/ann</td>
<td>.......... Ml/ann</td>
<td>.......... Ml/ann</td>
</tr>
</tbody>
</table>

Please comment if the totals are different to those shown as Volumes received in item 4 e.g. evaporative losses .................................................................

**Notes:**
1. Data should be consistent with items 7, 8 and 9.
2. **Include raw or partially treated wastewater discharged to land for treatment purposes on site.**

7. Volumes of effluent or wastewater discharged to land\(^*\)\(^*\).

<table>
<thead>
<tr>
<th></th>
<th>Now</th>
<th>By 2000</th>
<th>By 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MI/ann</td>
<td>MI/ann</td>
<td>MI/ann</td>
</tr>
<tr>
<td></td>
<td>MI/ann</td>
<td>MI/ann</td>
<td>MI/ann</td>
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<tr>
<td></td>
<td>MI/ann</td>
<td>MI/ann</td>
<td>MI/ann</td>
</tr>
<tr>
<td></td>
<td>MI/ann</td>
<td>MI/ann</td>
<td>MI/ann</td>
</tr>
</tbody>
</table>

**Urban situations:**
- Parks, Recreation areas
- Golf courses
- Market gardens, orchards etc
- Environmental flow for wetland protection etc
- Groundwater recharge by flooding (intentional)
- Disposal (no re-use value)
- Treatment\(^*\)\(^*\)
- Other

<table>
<thead>
<tr>
<th></th>
<th>Now</th>
<th>By 2000</th>
<th>By 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MI/a</td>
<td>MI/a</td>
<td>MI/a</td>
</tr>
<tr>
<td></td>
<td>MI/a</td>
<td>MI/a</td>
<td>MI/a</td>
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<tr>
<td></td>
<td>MI/a</td>
<td>MI/a</td>
<td>MI/a</td>
</tr>
<tr>
<td></td>
<td>MI/a</td>
<td>MI/a</td>
<td>MI/a</td>
</tr>
</tbody>
</table>

**Rural situations:**
- Market gardens, orchards etc
- Agriculture
- Forestry
- Irrigated pastures
- Environmental flow for wetland protection etc
- Groundwater recharge by flooding (intentional)
- Disposal (no re-use value)
- Treatment\(^*\)\(^*\)
- Other

<table>
<thead>
<tr>
<th></th>
<th>Now</th>
<th>By 2000</th>
<th>By 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MI/a</td>
<td>MI/a</td>
<td>MI/a</td>
</tr>
<tr>
<td></td>
<td>MI/a</td>
<td>MI/a</td>
<td>MI/a</td>
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<tr>
<td></td>
<td>MI/a</td>
<td>MI/a</td>
<td>MI/a</td>
</tr>
<tr>
<td></td>
<td>MI/a</td>
<td>MI/a</td>
<td>MI/a</td>
</tr>
</tbody>
</table>

Note: **Include raw or partially treated wastewater discharged to land for treatment purposes on site.**
8. Volumes of effluent for direct re-use.

<table>
<thead>
<tr>
<th>Nature of use</th>
<th>Now</th>
<th>By 2000</th>
<th>By 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>On site Plant purposes</td>
<td>Ml/a</td>
<td>Ml/a</td>
<td>Ml/a</td>
</tr>
<tr>
<td>Industrial</td>
<td>Ml/a</td>
<td>Ml/a</td>
<td>Ml/a</td>
</tr>
<tr>
<td>Third pipe urban</td>
<td>Ml/a</td>
<td>Ml/a</td>
<td>Ml/a</td>
</tr>
<tr>
<td>Aquaculture/mariculture</td>
<td>Ml/a</td>
<td>Ml/a</td>
<td>Ml/a</td>
</tr>
<tr>
<td>Ornamental water bodies</td>
<td>Ml/a</td>
<td>Ml/a</td>
<td>Ml/a</td>
</tr>
<tr>
<td>Groundwater recharge by injection</td>
<td>Ml/a</td>
<td>Ml/a</td>
<td>Ml/a</td>
</tr>
<tr>
<td>Other</td>
<td>Ml/a</td>
<td>Ml/a</td>
<td>Ml/a</td>
</tr>
<tr>
<td>Other</td>
<td>Ml/a</td>
<td>Ml/a</td>
<td>Ml/a</td>
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</table>

9. Volumes of effluent discharged to inland/fresh waterways

<table>
<thead>
<tr>
<th></th>
<th>Now</th>
<th>By 2000</th>
<th>By 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ml/ann.</td>
<td>Ml/ann.</td>
<td>Ml/ann.</td>
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</tbody>
</table>

Are beneficial uses presently made of the waterways? Yes / No

If yes, for what purpose(s)? Please tick squares.

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Now</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated agriculture (incl. forestry etc)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Urban Water Supply</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Recreation, fishing, boating, etc</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Commerce, tourism</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Protection of aquatic environment</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Other conservation</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Industrial purposes</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Other</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
10. What do you consider are the main impediments to greater wastewater re-use?
(Please tick up to 5 items for each of urban and rural)

<table>
<thead>
<tr>
<th>Impediments</th>
<th>Urban</th>
<th>Rural</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Cost issues</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Health issues/Risk</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Regulatory Agencies</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Public perception</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Environmental issues</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Materials/Standards</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Legal issues</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Technology/Research</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Guidelines</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Due Diligence issues</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

Comments: ..........................................................................................................

11. What Federal and/or State Government initiatives do you consider would promote greater re-use or use of wastewater? (Please tick up to 5 items for each of urban and rural).

<table>
<thead>
<tr>
<th>Initiatives</th>
<th>Urban</th>
<th>Rural</th>
<th>Urban</th>
<th>Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot studies</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Technological developments</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Research Grants</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>National data base</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Real cost water pricing</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Less regulation</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Integrated planning</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Appropriate zoning</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

Comments: ..........................................................................................................

12. Does the State/Territory/Authority have available recent relevant scientific or community studies or surveys which would help to overcome impediments or assist with initiatives for greater use or re-use of wastewater e.g. public attitude surveys, epidemiological studies?

Yes/No

If available, please list documents:
..........................................................................................................
..........................................................................................................
..........................................................................................................

13. Contact person within the State/Territory/Authority

Name.................................................................
Title.................................................................
Phone...................................... Facsimile............................. Date..............
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GLOSSARY OF TERMS

Best Management Practices (BMP): This term is often used in reference to various desirable techniques of stormwater management.

Biochemical oxygen demand (BOD): The oxygen absorbed by a sewage or effluent sample in 5 days at 20°C. A low BOD indicates that the sample is low in those chemicals which consume oxygen in their breakdown.

Brine: A very salty liquid stream generated during reverse osmosis technology and requires special disposal.

Combined Sewer Overflows (CSO): These occur during periods of heavy rain, when purpose-built structures in the sewerage system overflow, as a result of stormwater loads.

Constructed wetlands system: A series of ponds in which aquatic plants absorb nutrients and other pollutants from water.

Direct potable re-use: The planned potable use of treated wastewater delivered directly into the water supply system.

Disinfection: A process which destroys, inactivates or removes pathogenic microorganisms.

Dual reticulation system: A water supply system with two separate sets of pipes, one for potable water and the other for non-potable water.

Effluent: The water that is discharged from a wastewater treatment plant.

Equivalent person (EP): Unit used in describing the size and capacity of various parts of a sewerage system. This has been defined as 240L/day.

Gigalitre: (GL) = 10^9 L

Indirect potable reuse: The potable use of treated wastewater, which is discharged into surface or underground waters and is used again in its diluted form.

Marginal cost: The cost of making an additional unit of water available (the sum of the marginal capacity and operating cost).

Megalitre: (ML) = 10^6 L

Nutrient removal: Removal of nitrogen and phosphorus from wastewater to prevent excessive aquatic plant regrowth in receiving waters.

Polishing: Refinement of the quality of highly treated effluent by additional removal of nutrients and other pollutants.

Potable re-use: Re-use of highly treated wastewater for drinking.

Potable water: Water which is suitable for human consumption either as drinking water or in food preparation.

Primary treatment: Initial wastewater treatment, involving screening, grit removal and sedimentation to remove settleable solids from wastewater.

Recycled/Reclaimed water: Water derived from wastewater and treated to a standard which allows its reuse in applications such as watering lawns, washing cars and industrial cleaning.

Reverse osmosis: An advanced method used in water and wastewater treatment which relies on a semipermeable membrane to separate the water from impurities.

Secondary treatment: The biological decomposition or conversion of dissolved or suspended organic matter into a form that reduces its environmental impact.

Suspected solids (SS): Undissolved constituents of wastewater.

Sewage: The wastewater from homes, offices, shops and factories. Trade waste from industry may also be present.

Sewage effluent: Liquid discharge from a sewage treatment plant after treatment.

Sewerage: The system of pipes in which sewage flows.

Sewer mining: Diversion and treatment of raw sewage, for on-site purposes such as irrigation.

Stormwater: The water that falls on urban surfaces and either infiltrates the ground, collects in lakes or wetlands, evaporates or runs off in natural or constructed drains.

Tertiary treatment: The treatment of wastewater beyond the secondary stage. This may involve further removal of nutrients, pathogens and suspended particles, by flocculation and coagulation, followed by clarification, filtration, and disinfection.

Total water cycle management: The integration of land use planning with the management of water supply; stormwater drainage; and wastewater collection, treatment and disposal.

Wastewater: Untreated sewage.

Wastewaters: Sewage plus stormwater.

Water re-use: The successive use of water, following treatment of wastewater and conveyance to point of use.

Water recycling: Water re-use, usually in a closed system, or re-use of water in the same establishment for a lower grade or similar use, as in certain industrial processes such as cooling towers and boilers.
ACRONYMS

ACTEW Australian Capital Territory Electricity and Water
ACTPA Australian Capital Territory Planning Authority
AIUS Australian Institute of Urban Studies
ANZECC Australian and New Zealand Environment and Conservation Council
ARCWIS Australian Research Centre for Water In Society
ARMCANZ Agriculture and Resource Management Council of Australia and New Zealand
AWRC Australian Water Resources Council
BCP Better Cities Program
CEPA Commonwealth Environmental Protection Agency
COAG Council of Australian Governments
EPA Environmental Protection Agency/Authority
E&WS Engineering and Water Supply Department, South Australia
HWC Hunter Water Corporation
IUCN International Union for the Conservation of Nature
MCPHLG Ministerial Council for Planning, Housing and Local Government
MFP Multi Function Polis
NCAP National Coastal Action Program
NHMRC National Health and Medical Research Council
NPDES National Pollution Discharge Elimination Scheme
NRA National River Authority, UK
NTP&WC Northern Territory Power and Water Corporation
NWQMS National Water Quality Management Strategy
OFWAT Office of Water Services, United Kingdom
O&M Operating and Maintenance
RAC Resource Assessment Commission
SCARM Standing Committee on Agriculture and Resource Management
SOMER State of the Marine Environment Report
STP Sewage Treatment Plant
TCM Total Catchment Management
USEPA United States Environmental Protection Agency
UWRAA Urban Water Research Association of Australia
WAWA Water Authority of Western Australia
WAWC Western Australian Water Corporation
WSAA Water Services Association of Australia
WRMC Water Resource and Management Committee
WSUD Water Sensitive Urban Design
WTC Water Technology Committee
WTP Wastewater Treatment Plant